2020–2021

DROUGHT IN THE U.S. NORTHERN PLAINS AND CANADIAN PRAIRIES

INITIAL ASSESSMENT OF IMPACTS AND RESPONSE TO BUILD RESILIENCE DURING AN ONGOING DROUGHT

NOAA

NIDIS

ACKNOWLEDGEMENTS

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On the Cover: Aerial view of canola field in poor condition due to drought. Credit: Igor Stevanovic

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Early 2020
The U.S. Northern Plains and Canadian Prairies were largely free of drought. Much of the region had ample soil moisture reserves.

Spring–Early Summer 2020
Dry conditions began to take hold. North Dakota and Wyoming were the first states to have widespread moderate drought (D1).

June 2020
The Wyoming Conditions Monitoring Team (WCMT) formed in response to deteriorating conditions. A large area of D1, along with pockets of severe drought (D2), developed in Saskatchewan.

June–August 2020
As abnormally dry and drought conditions spread across the region, drought rapidly expanded and intensified in Wyoming.

September 2020
The Mullen Fire in southern Wyoming and northern Colorado burned over 175,000 acres.

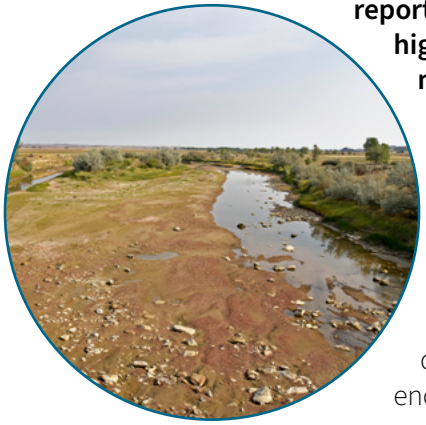
September–November 2020
Drought became more entrenched. D2 developed across eastern and central portions of the region. Exceptional drought (D4) developed in Wyoming.

November 2020
Precipitation deficits were high, surface water supplies were dwindling, and soil moisture was largely depleted across the region.

Mid-January 2021
An historic windstorm swept the region. With little to no plains snowpack and low relative humidities, fire danger increased and several grass fires ignited.

EXECUTIVE SUMMARY

The 2020–2021 drought of the greater U.S. Northern Plains and Canadian Prairies was a multi-billion-dollar event that had wide-reaching impacts on the region's communities, ecosystems, water resources, and agricultural systems. Building off of the lessons learned from the flash drought of 2017—the last drought to affect the region—this report advances understanding of drought response and preparedness actions by highlighting new efforts, along with outstanding gaps and needs. This assessment is being released now so that the lessons learned can inform preparedness and response activities even as drought continues into 2022.



▲ **From its source in the Bighorn Mountains in central Wyoming to its union with the Yellowstone River, the Powder River is 250 miles long and is an important local source for grazing, irrigation and wildlife. Credit: Michael Downey**

DROUGHT EVOLUTION

• Prior to the onset of the 2020–2021 drought, portions of the U.S. Northern Plains and Canadian Prairies were emerging from one of the most extreme wet periods on record. These wet conditions gave way to dryness in 2020, with drought conditions initially developing in the spring, and slowly intensifying and expanding to encompass much of the region by autumn 2020.

• Extremely dry conditions persisted over the winter of 2020–2021 and throughout the first half of 2021, with intense heat building during the summer months. Drought expanded and intensified throughout the region. By the time widespread precipitation arrived in the late summer and autumn, it was too late in the year to provide relief for drought-stricken crops, pastures, and rangelands. Regional drought coverage peaked in late summer 2021.

• Subsequent precipitation over the winter of 2021–2022 and spring 2022 improved drought conditions considerably; however, drought still persisted across southern portions of Alberta and Saskatchewan, western and southern portions of South Dakota, and the majority of Montana and Wyoming at the end of May 2022.

January–February 2021
Drought continued to expand over the winter months, which is atypical in this region. North Dakota State University (NDSU) Extension started drought preparedness webinars for farmers and ranchers.

March 2021
The WCMT initiated a monthly webinar series in an effort to provide two-way communication about current conditions and on-the-ground impacts. At the end of March, a state of emergency due to drought and fire was declared in South Dakota. A few pockets of extreme drought (D3) emerged in southern Manitoba.

April 2021
The Drought Hotline and Interactive Hay Map in North Dakota were reactivated.

Spring 2021
Thousands of acres burned, including parts of Theodore Roosevelt National Park in North Dakota and areas near Mount Rushmore National Monument in South Dakota.

March–April 2021
By March 9, 2021, the entire state of North Dakota was experiencing drought for the first time since the drought of 2012. A statewide wildfire emergency and statewide drought disaster were declared in early April in North Dakota.

April–May 2021
Although drought remained in many areas, conditions improved considerably in Wyoming. This reprieve was short-lived. In May, an area of D4 developed in Manitoba for the first time since the inception of the Canadian Drought Monitor. Nearly 85% of North Dakota was in extreme drought (D3) or worse, a new record.

▲ Timeline of key events. Credit: NIDIS, Fiona Martin

- Overall, drought generally evolved slowly during 2020 and 2021, expanding and contracting, intensifying and improving as conditions changed. The epicenter of the drought shifted locations several times over the two-year period. Unlike the flash drought of 2017, this drought was not just confined to the U.S. Northern Plains and Canadian Prairies. A broad area of the western U.S. and Canada was also impacted during this time.

DROUGHT IMPACTS

- The drought of 2021 was intense and widespread. It was the worst single-year drought in over 70 years in Canada, impacting close to 55 million acres of crop land, nearly 50 million acres of pasture land, and over 1.6 million head of cattle across the Prairie region. For the U.S. Northern Plains, it was the most widespread drought in over 20 years, impacting nearly 98% of the region at its furthest extent.
- With Tribal Nations located throughout the U.S. Northern Plains, local drought impacts varied depending on location. However, many Tribal Nations reported impacts related to agriculture, ecosystems, water resources, and human health. Drought also had an impact on cultural resources and practices.

▲ The 58-year-old Grub Reservoir dam, which attracts many recreational visitors to its approximately 690-surface-acre reservoir amidst more than 500,000 acres of BLM-managed lands. Credit: Michael Downey

- Some communities across the U.S. Northern Plains and Canadian Prairies implemented voluntary, and in some cases mandatory, water restrictions at various times during the drought. In Canada, some communities worked with the Water Security Agency to develop Hydrologic Drought Preparedness Plans.
- Below-average runoff caused reductions in hydroelectric power production across the region. In the Canadian Prairies, hydroelectric power production was the lowest in decades.
- Over 6.5 million acres burned across the U.S. Northern Plains and Canadian Prairies in 2021. In Manitoba, it was the worst fire season since 1989, another historic drought year.

▲ Timeline of key events (cont.). Credit: NIDIS, Fiona Martin

- Agriculture across the region was impacted by the drought. With forage and hay production down significantly across much of the western U.S. and Canada, scarce feed supplies and dwindling water resources caused ranchers to cull herds. Overall, herds were reduced by about 5–10% in both the U.S. Northern Plains and Canadian Prairies in 2021 alone. Some, but not all, crops also had large reductions in production in 2021.
- The quantity and quality of water supplies for livestock was impacted by the drought. In many areas, ranchers were forced to haul water to herds. There was an increase in cyanobacteria blooms and testing indicated that some water sources were in poor quality due to high levels of salts and minerals. Although not a widespread occurrence, there were reports of cattle deaths due to poor water quality.
- Grasshoppers were a major issue in parts of the region, competing with cattle for pasture and forage, and stripping some crops bare. Blister beetles, which tend to accompany high grasshopper populations, were also a concern as they are toxic to cattle and horses, if eaten.
- Habitat degradation, scarce water resources, and disease affected wildlife across the region, with negative impacts being reported to fish, pronghorn antelope, upland birds, waterfowl, and white-tailed deer, to name a few.

DROUGHT RESPONSE

- In 2021, 17 drought-related executive orders were signed by the governors in the U.S. Northern Plains states, including 4 in Montana, 6 in North Dakota, 4 in South Dakota, and 3 in Wyoming.
- Although response varied based on local conditions, some Tribal Nations implemented fire restrictions/bans and declared drought and/or fire emergencies.
- State monitoring teams, including the newly formed Wyoming Conditions Monitoring Team (WCMT), helped provide robust recommendations to the U.S. Drought Monitor authors.

August 2021
Although rains arrived in August, precipitation deficits were so high and impacts were so far-reaching that few improvements were made. When drought peaked at the end of summer, just over 74 percent of the region was in at least moderate drought (D1).

September 2021
The entire state of Montana was in at least severe drought (D2) for seven consecutive weeks starting in late September. This was the first time in the history of the U.S. Drought Monitor that the entire state was in at least the D2 designation.

October 2021
Widespread precipitation across the Dakotas helped improve or remove drought conditions in the short-term, but long-term deficits and impacts remained. Montana largely missed out on this precipitation.

December 2021
The annual runoff for the Missouri River Basin above Sioux City, Iowa was the 10th lowest on record.

Winter 2021–2022
Although improvements occurred over the winter, drought persisted across much of the region heading into the growing season. Drought expanded in South Dakota.

Spring 2022
Precipitation continued to improve overall drought conditions. By the end of May, North Dakota and Manitoba were drought-free. Despite these improvements, drought conditions persisted and, in some isolated cases, expanded in other parts of the region.

- The U.S. Department of Agriculture (USDA) Emergency Assistance for Livestock, Honey Bees and Farm-raised Fish Program (ELAP) was expanded in 2021 to help offset the costs of transporting feed for grazed livestock. A number of other assistance programs were available for affected farmers and ranchers, including the USDA's Livestock Forage Disaster Program (LFP), the Livestock Indemnity Program (LIP), emergency loans, and others.
- Up to $825 million in cost-shared AgriRecovery funding was made available by the Government of Canada, along with the governments of Alberta, British Columbia, Manitoba, Ontario, and Saskatchewan. Other relief efforts that provided assistance included, but were not limited to, the AgriStability Program, the Livestock Tax Deferral provision, and the AgriInsurance Program.
- Producers in need of hay were connected to hay sellers/donors through various online platforms, such as the Montana Department of Agriculture Hay Hotline and the South Dakota State University (SDSU) Extension Feed & Forage Finder Facebook group. In Canada, producers were connected through the Hay West 2021 Initiative, as well as provincial forage networks.
- In an effort to increase federal interagency coordination on drought response, NOAA's National Integrated Drought Information System (NIDIS) partnered with the Federal Emergency Management Agency (FEMA Region 8) to bring together federal partners to give updates on support and services available to regional stakeholders. NIDIS also virtually convened state partners on a regular basis, coordinating work on drought monitoring and response, and facilitating regional discussion around current conditions and needs.
- Timely drought information was disseminated to the public through social media and a variety of webinar series, often in collaboration with federal, state, and academic partners. University Extension played a key role in webinar development across the region. Drought information was also disseminated through various climate summaries and drought status updates. NIDIS, along with other federal partners, produced several Drought Status Updates with up-to-date drought information and outlooks, which received around 6,500 online views

▲ Spring wheat crop near Wolf Point, Montana. Photo taken August 27th, 2021. Credit: Michael Downey

overall. In Canada, Agriculture and Agri-Food Canada's National Agroclimate Information Service disseminated information on the drought status through its Drought Watch website, as well as numerous webinars and briefings.

- The Northern Plains Drought Update & Outlook Tribal Webinar series ran from late May through early December 2021 and provided timely information about how tribes were responding to drought, current conditions and outlooks, and drought resources available for Tribal Nations in the region.

- Many groups in the U.S. Northern Plains states and Canadian Prairie provinces promoted the use of the Condition Monitoring Observer Reports on Drought (CMOR-Drought) and the Agroclimate Impact Reporter tool, respectively, in order to better assess local drought conditions. Some states and provinces held monthly calls with producers and other stakeholders to solicit input directly on the status of local drought conditions. At the height of the drought, some committees were meeting weekly.

▲ **Damage to canola crops including heat blast and stunted growth. Photo taken by Alyssa Klein (AAFC) on July 11, 2021 on a farm close to Belle Plaine, Saskatchewan.**

BUILDING RESILIENCE: NEW AND ONGOING NEEDS AND GAPS

This list represents new and ongoing needs and gaps. Some of these were identified by both the 2017 assessment as well as this assessment (marked with asterisks). Efforts are underway to address many of these needs.

- Organized monitoring networks need to be maintained and expanded in order to provide observations that support drought assessment, prediction, and research. This includes soil moisture, which is a key drought indicator in the region. Current federal investments to increase monitoring stations in the U.S. Northern Plains will help address these gaps in the long-term, but the immediate need remains. Research into related topics such as the role of remote sensing in data sparse regions, soil moisture infiltration dynamics, and soil moisture modeling is also needed.*

- There is a continued need for a greater density of on-the-ground impact reporting in both the U.S. and Canada.*

- Understanding how new and existing drought indicators and indices perform at various spatial and temporal scales has improved since 2017; however, there is a need to evaluate additional metrics across the region.*

- Local conditions, such as the quality of stock ponds, were perceived as drought early warning indicators. More research into local indicators like these could deliver earlier warnings of drought.*

- More communication regarding available drought relief and/or management programs is needed as there are a number of federal, state, and provincial agencies that provide assistance for drought-related infrastructure improvements, planning, and losses.*

- There is a need to develop best practices for use of metrics during periods of drought recovery.

- The development of new products and tools that take into account the timing and duration of precipitation events is needed to more easily provide context for these events.
- There is interest in better understanding the relationship between drought and wildland fire in the region. For example, is there a correlation between the U.S. Drought Monitor categories and fire risk? How can climate data inform wildland fire-specific tools?
- The development of best practices for communication during longer-term droughts could help improve outreach to partners and the public. What are the most effective ways to communicate about drought as it continues over months, seasons, and years?
- There is a need to expand discussions of drought conditions and impacts to include more concrete responses and actions. The development of tangible actions by sector would be beneficial for federal, state, and provincial agencies to use.
- In Canada, there is a need for better collaboration and communication on drought and weather impacts between various federal, provincial, private, and sector-specific groups; this includes more open sharing of data and information on a timely basis, especially between different provincial groups.
- The 2020–2021 drought coincided with the start of the COVID-19 pandemic. Research into the ways the two disasters impacted one another in terms of response is needed. □

INTRODUCTION

Prior to the onset of drought in early 2020, portions of the north central United States and southern Canadian Prairies were emerging from one of the most extreme wet periods on record (Environment and Climate Change Canada 2020; Umphlett et al. 2020). These wet conditions gave way to dryness in 2020, with drought conditions developing in the spring and slowly intensifying and expanding to encompass much of the U.S. Northern Plains and Canadian Prairies[1] by autumn. Extremely dry conditions persisted over the winter and throughout 2021, with intense heat building during the summer months.

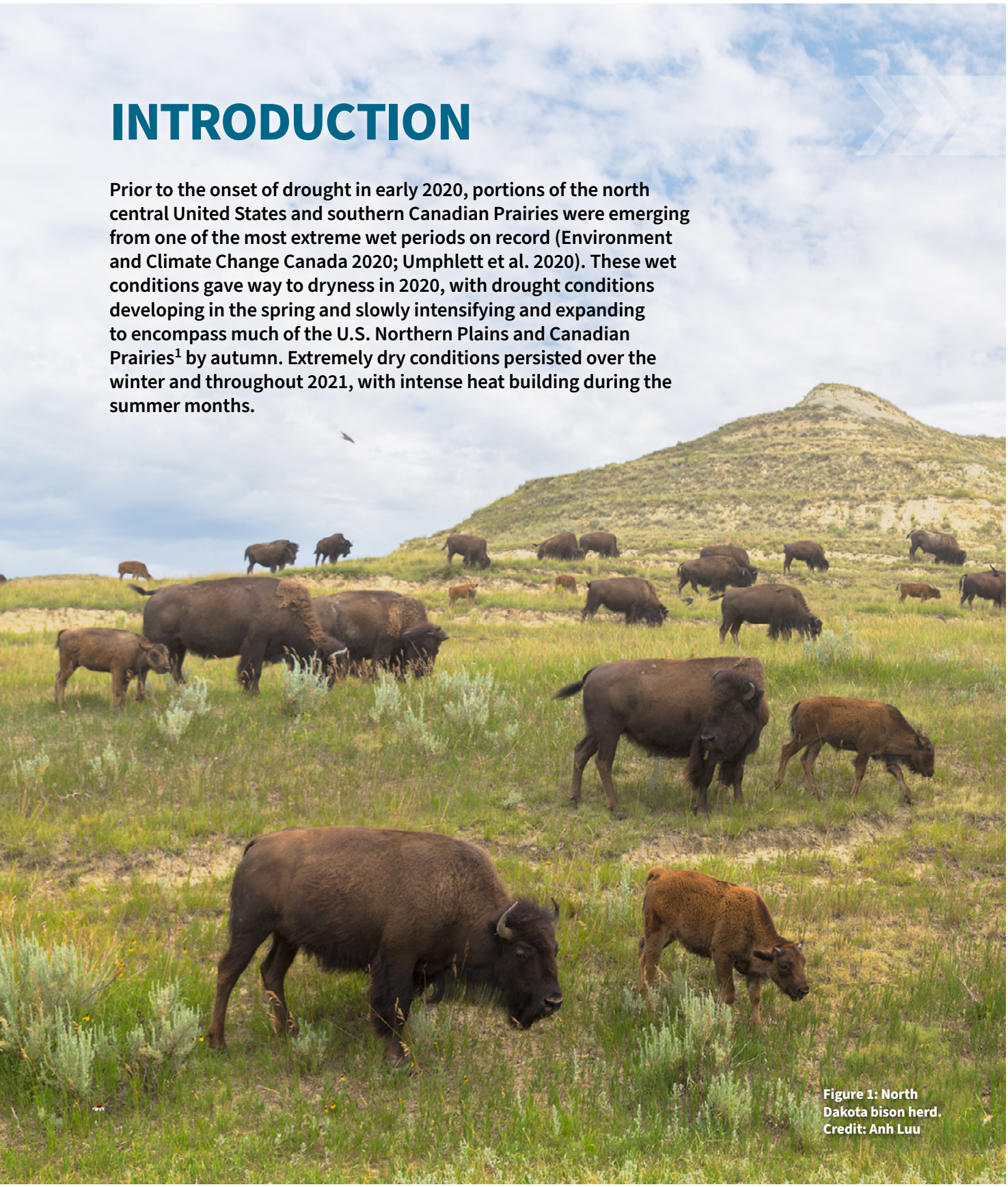
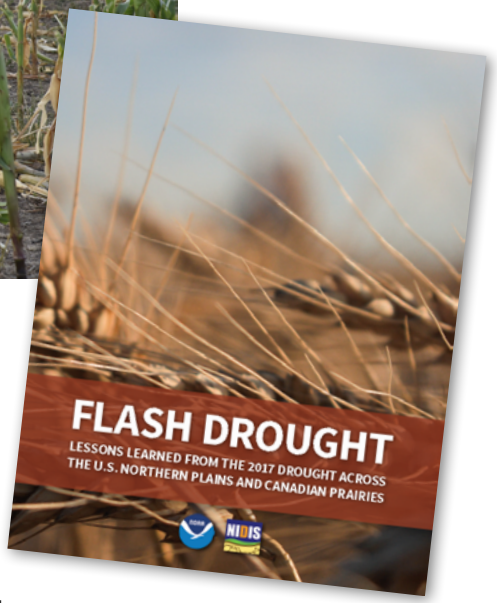


Figure 1: North Dakota bison herd. Credit: Anh Luu

◄ **Figure 2: Drought-damaged cornfield near Baker, Montana on August 27, 2021. Michael Downey**



▲ **Figure 3: Cover of *Flash Drought: Lessons Learned from the 2017 Drought Across the U.S. Northern Plains and Canadian Prairies.* Credit: NOAA NIDIS**

This combination of conditions, along with depleted soil moisture and reduced streamflows, continued the expansion and intensification of drought conditions throughout the region with a peak in drought coverage in late summer 2021. Even when precipitation arrived, impacts remained and drought continued to be a persistent regional feature throughout the end of the year and into 2022. Impacts from the drought have been felt in the region's communities, ecosystems, water resources, and agricultural systems, with initial indications showing that the losses from 2021 have totaled over $4 billion in this region alone (Environment and Climate Change Canada 2021; NOAA NCEI 2022a).

In 2017, one of the worst droughts in decades struck portions of this same region, developing rapidly and causing wide-reaching impacts. Due to the unique nature of the drought, NOAA's National Integrated Drought Information System (NIDIS) and partners documented the impacts, responses, lessons learned, and outstanding needs in affected states, provinces, and Tribal Nations in *Flash Drought: Lessons Learned from the 2017 Drought Across the U.S. Northern Plains and Canadian Prairies* (Jencso et al. 2019). This report provided an opportunity to reflect upon the state of drought response and preparedness in the region at the time, and ways to better prepare for future droughts.

Building off of the last effort, this assessment will continue the conversation surrounding drought response and preparedness in the region, and provide insight into the lessons learned since the drought of 2017, along with gaps, outstanding needs, and future work. Insights gained from this assessment will be helpful for building drought resilience not just in the U.S. Northern Plains and Canadian Prairies, but other parts of the Missouri River Basin Drought Early Warning System (DEWS) and beyond. □

1 Drought also impacted neighboring areas of the U.S. and Canada during this time. In fact, parts of the western U.S. were in the midst of a megadrought—a drought that lasts about two decades or longer. A recent study showed that this megadrought is the most severe in about 1,200 years (Williams et al. 2022).

Figure 4: Spring wheat crop near Wolf Point, Montana on August 27th, 2021. Credit: Michael Downey

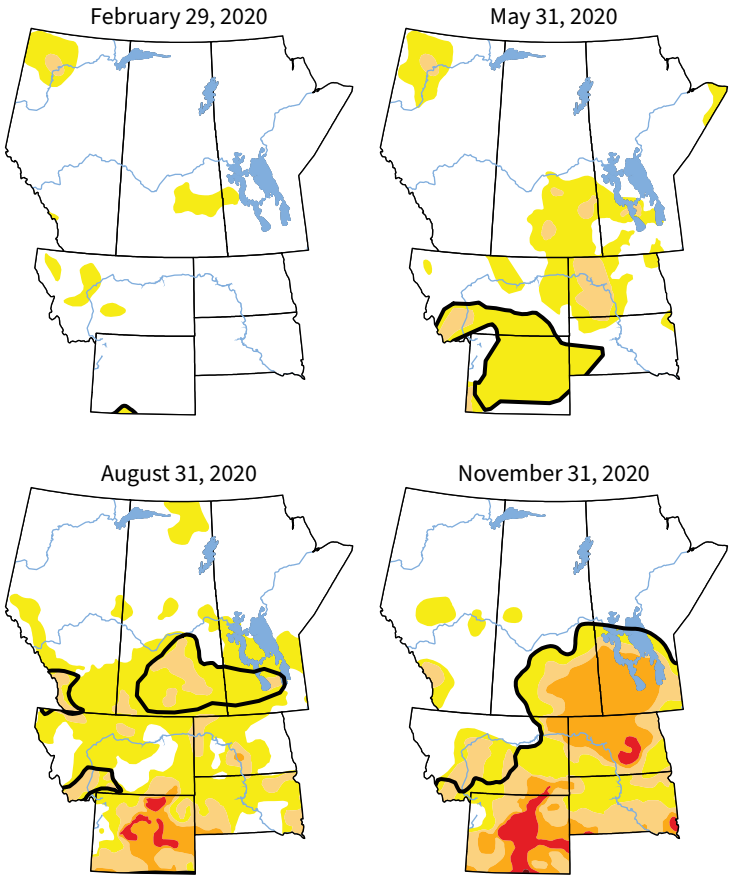
DROUGHT: EVOLUTION, IMPACTS, & NEW RESPONSE

SPRING 2020: DRY CONDITIONS EMERGE AFTER PERIOD OF EXTREME WETNESS

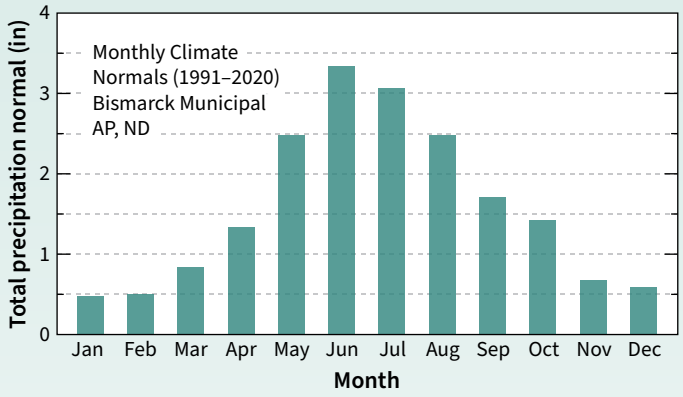
For the U.S. Northern Plains and Canadian Prairies, 2020 started largely free of drought. Some areas of the region had ample soil moisture locked in frozen soils, waiting for the spring thaw. Portions of North Dakota, Montana, and southern Canada were so wet that unharvested crops were still in fields. Water resources were abundant, with some rivers running high even over the winter. At the end of winter 2019–2020, less than 1% of the region was in drought (*Figure 5, next page*).

Dry conditions began to take hold during the spring. In fact, the spring of 2020 was the first season in over two years that any state in the U.S. Northern Plains ranked among the top 10 driest.[2] North Dakota, with its 9th driest spring on record, broke that streak. Generally, drier conditions across the region initially had benefits by reducing the overall flood risk and impacts, and allowing for significant planting progress in many areas. Even with the drier conditions, some areas still contended with flooding and wet, muddy soils, especially across North Dakota. As precipitation deficits slowly accrued, abnormally dry conditions (D0) spread and pockets of moderate drought (D1) developed (*Figure 5*). Overall, drought impacts were limited at this time. Despite the drier conditions on the plains, Rocky Mountain snowpack in the upper Missouri Basin fared well, peaking in mid-April with an above-normal

2 Statewide temperature and precipitation data provided by NCEI, Climate at a Glance. Period of record begins 1895.



◄ Figure 5: North American Drought Monitor (NADM) Maps at the end of each climatological season in 2020, showing the progression of the drought across the U.S. Northern Plains and Canadian Prairies. Source: NOAA/NCEI, NDMC



◄ Figure 6: Monthly precipitation normals for Bismarck Municipal Airport, North Dakota.

Timing is Everything

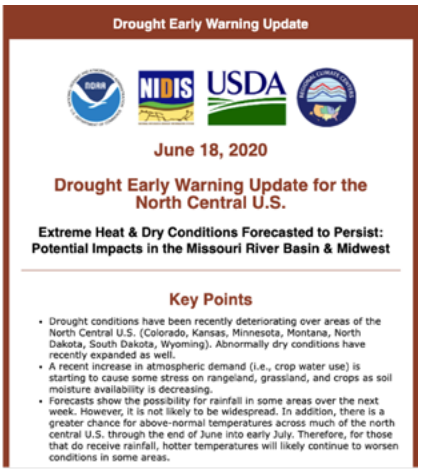
Late spring and summer is the wettest time of the year for the plains portions of the U.S. Northern Plains and Canadian Prairies (*Figure 6*). In many areas, precipitation during the months of April through June accounts for roughly 40% of the annual total alone. If precipitation does not materialize during this timeframe, it can be very difficult to make up these deficits because precipitation typically declines moving into the autumn season. In fact, failed rains during the late spring and early summer were the main cause of the 2017 flash drought (Hoell et al. 2019). Monthly precipitation normals data obtained via the Applied Climate Information System (ACIS).

snow water equivalent (109% of the normal peak above Fort Peck; 112% of the normal peak in the reach from Fort Peck to Garrison). At the end of spring, monthly average streamflows across the region were generally normal to much above normal, with a few exceptions in isolated areas.

SUMMER 2020: DROUGHT EXPANDS WITH RAPID DEVELOPMENT IN WYOMING

Generally warm and dry conditions over the summer of 2020 caused abnormal dryness and drought to expand substantially across the region. Within this expansion, Wyoming experienced rapid drought development, with the statewide drought (D1–D4) coverage increasing from about 2% at the beginning of June to over 73% at the end of August. At times, the dry conditions were coupled with above-normal temperatures and low relative humidities,

which increased evaporative demand, dried soils, and stressed vegetation. The end of the summer was particularly hot and dry, with Wyoming having its 3rd warmest and 5th driest August on record. Impacts to the livestock industry were reported during this time as pasture and rangeland conditions declined across the state and some surface water supplies, like stock ponds and dugouts, were low and had poor water quality. In response, many producers had to haul water or provide supplemental hay to livestock. (More detailed information on the overall impacts to the livestock industry may be found on *page 26*.)


Drought Early Warning Update

NIDIS USDA

June 18, 2020

Drought Early Warning Update for the North Central U.S.

Extreme Heat & Dry Conditions Forecasted to Persist: Potential Impacts in the Missouri River Basin & Midwest

Key Points

- Drought conditions have been recently deteriorating over areas of the North Central U.S. (Colorado, Kansas, Minnesota, Montana, North Dakota, South Dakota, Wyoming). Abnormally dry conditions have recently expanded as well.
- A recent increase in atmospheric demand (i.e., crop water use) is starting to cause some stress on rangeland, grassland, and crops as soil moisture availability is decreasing.
- Forecasts show the possibility for rainfall in some areas over the next week. However, it is not likely to be widespread. In addition, there is a greater chance for above-normal temperatures across much of the north central U.S. through the end of June into early July. Therefore, for those that do receive rainfall, hotter temperatures will likely continue to worsen conditions in some areas.

▲ **Figure 7: During the drought, NIDIS worked with other NOAA colleagues, as well as other federal agencies to provide up-to-date information on the drought and its impacts through Drought Early Warning Updates, Drought Status Updates, the monthly North Central Drought and Climate Outlook webinar series, and the seasonal National Weather Service Hazard Outlooks for the region. This screenshot shows the first Drought Early Warning Update of the drought from NIDIS and its partners, which was released on June 18, 2020.**

Although the most intense drought conditions over the summer were largely centered over Wyoming, other areas of the region were dry as well. Accumulating precipitation deficits caused moderate drought (D1) to expand across portions of eastern Montana, western South Dakota, western and central North Dakota, and southern Saskatchewan in June 2020. A few small pockets of severe drought (D2) also developed during this time. By the end of June, the first half of the year was the 6th driest on record for North Dakota. These dry conditions were reflected in drying soils and below- or much below-normal streamflows in some areas. Beneficial rains in late June and early July helped improve or alleviate drought, especially across much of western North Dakota and southern Saskatchewan. However, this reprieve was fairly short-lived as drought would redevelop and intensify in the coming months.

By the end of the summer, nearly half of the region was experiencing abnormally dry (D0) or drought (D1–D4) conditions, with severe (D2) and extreme drought (D3) largely confined to Wyoming (*Figure 5*).

AUTUMN 2020: SETTING THE STAGE FOR INTENSE DROUGHT IN 2021

Precipitation deficits continued to mount through the end of 2020, with much of the region receiving no more than half of normal precipitation during autumn. Although precipitation is typically lighter at this time of the year, it is important for autumn seeding and for soil moisture recharge at the end of the growing season. Early season snows did bring moisture to the region, but this only slowed the intensification and expansion of the drought.

Impacts at this time were mixed. On the one hand, dry conditions generally allowed for a quick harvest, but fall seeding was impacted in some areas. Poor pasture and range conditions also continued to impact livestock producers, especially in Wyoming and North Dakota. Even with drought spreading across the region, row crops fared well in 2020. According to the USDA's Crop Production 2020 Summary (USDA NASS 2021), record high yields were estimated for several crops, such as barley (Montana), canola (North Dakota), corn (South Dakota), spring wheat (Montana and North Dakota), and winter wheat (Montana and South Dakota). Yields across the Canadian Prairies were also higher than average for most major field crops.

Throughout the autumn season, drought became more solidly entrenched in the region. Much of this expansion occurred in October, when a large area of severe drought (D2) developed across east-central portions of the region. In southern Canada, where much of this expansion took place, precipitation over the previous three months was as low as 40% of normal in some areas. In Regina, Saskatchewan, October 2020 precipitation was only 11% of normal. Nearly 80% of the Canadian Prairie region's agricultural lands were depicted as abnormally dry (D0) or in drought (D1–D4) at the end of October. The vast majority of this

◂ **Figure 8: Wyoming Conditions Monitoring Team consists of representatives from these agencies and entities.**

Wyoming Conditions Monitoring Team Forms in Response to Drought

In response to deteriorating conditions in early summer of 2020, the Wyoming Conditions Monitoring Team (WCMT) formed in mid-June. The team supports drought monitoring in the state by 1) helping to provide additional input and verification of drought recommendations prior to them being sent to the U.S. Drought Monitor author, 2) emphasizing the importance of conditions reporting to constituents, and 3) providing education and outreach.

Since the inception of WCMT, there has been an increase in the number of conditions reports going to the Community Collaborative Rain, Hail and Snow Network (CoCoRaHS) and Condition Monitoring Observer Reports on Drought (CMOR-Drought). These reports particularly helped highlight areas that needed further scrutiny (i.e., potential improvements or degradations in conditions). The WCMT also started a monthly webinar series in 2021 for resource managers and invited public servants in order to brief them on current conditions and outlooks. These webinars are recorded and made available for viewing by the public.

Team members consist of representatives from agencies and entities whose constituents are directly impacted by drought conditions. Examples of the many partners involved include the Wyoming State Climate Office; University of Wyoming Extension; Wyoming State Engineer's Office; Wyoming Game & Fish Department; Wyoming Office of Homeland Security; USDA Farm Service Agency, Natural Resources Conservation Service, and Northern Plains Climate Hub; five National Weather Service Weather Forecast Offices; U.S. Geological Survey (USGS); among others.

area remained in drought through the end of the year.

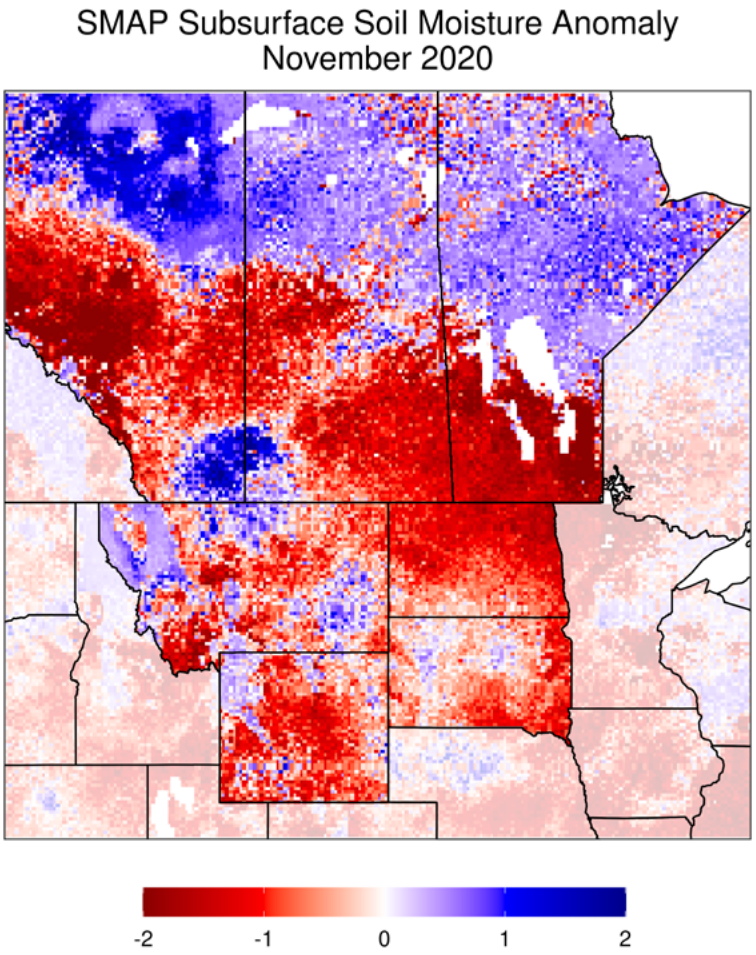
Overall, conditions going into the winter were bleak in many areas (*Figure 5*). Precipitation deficits were high, surface water supplies were dwindling, and soil moisture was largely depleted across the region (*Figure 9*). Dry soils were in place during freeze up in the Canadian Prairies and opportunities for soil moisture recharge in the U.S. Northern Plains were coming to a close. 2020 was ultimately one of the driest years on record for portions of the region. It was the 5th driest year for Wyoming, 8th driest year for North Dakota, and it was the driest year on record for local areas like Estevan, Saskatchewan (period of record 1899–2020) and Winnipeg, Manitoba (period of record 1938–2020). It was clear that precipitation over the coming months, especially in the early spring, would be critical for the upcoming growing season.

WINTER 2020–2021: DRY CONDITIONS CONTINUED INTO 2021

Relatively warm and dry conditions continued for much of the 2020–2021 winter, especially in December and January. Although still early in the season, mountain snowpack in the upper Missouri Basin was off to a slow start in these months, with mountain snow water equivalent below average above Fort Peck Reservoir and between Fort Peck and Garrison Reservoirs. For much of the region, snowfall was largely

lacking on the plains. In places without a solid snowpack, dried vegetation from the previous growing season was susceptible to fire, especially on days with gusty winds and low relative humidities. For example, a widespread high wind event in mid-January increased the fire danger, with several grass fires igniting in parts of the U.S. Northern Plains. The largest fire during this event was the Windy Fire, which started in southwestern North Dakota and quickly spread to the southeast near the town of Lemmon, SD, ultimately burning over 15,000 acres (NIFC 2021).

It was still fairly dry in February when conditions turned colder, with higher precipitation totals confined to portions of Montana and Wyoming. While this precipitation did boost mountain snowpack, overall, it was a dry winter across the region. For some areas of western North Dakota and eastern Montana, it was the driest winter on record, since 1895. Southern Manitoba also reported a very dry winter, with less than 40% of normal precipitation falling between November 2020 and March 2021. The continuation of dry conditions over the winter months caused drought to expand, which is atypical at this time of the year for the region (*Figure 10*).



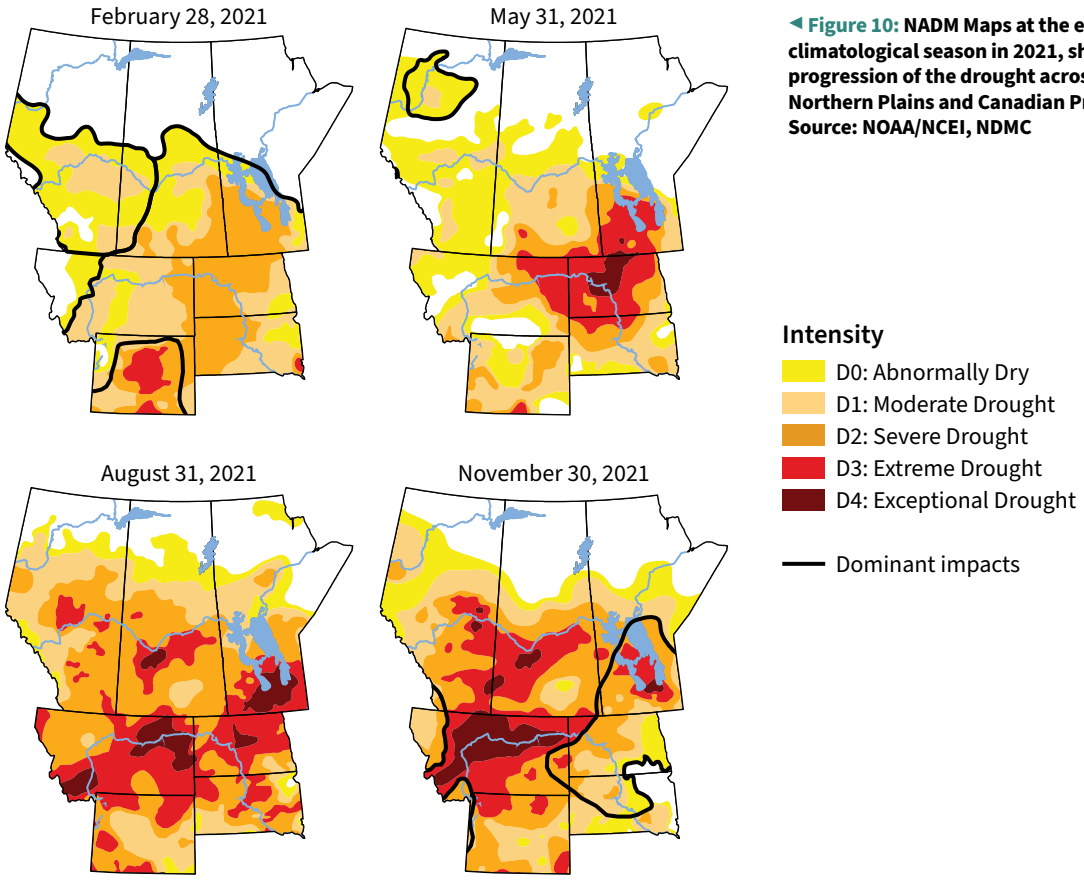
▲ **Figure 9: NASA Soil Moisture Active Passive (SMAP) Level 3 subsurface soil moisture anomaly data show that much of the U.S. Northern Plains and Canadian Prairies were abnormally dry going into winter. This map displays the average (median) SMAP subsurface soil moisture anomaly estimates for November 2020. Credit: Montana Climate Office**

Webinars Provided Timely Drought Information to Farmers and Ranchers

With drought likely to extend into the grazing season, North Dakota State University (NDSU) Extension hosted a number of webinars designed specifically for ranchers. In February and March of 2021, initial webinars focused on preparing for drought, while monthly Navigating Drought on Your Ranch webinars from April through October were more focused on drought response. Example topics included updates on local drought conditions, grazing and herd management strategies, available relief programs, and ways to manage stress. According to NDSU Extension, these webinars helped several ranchers make changes in their management decisions. Webinars resumed in the spring of 2022 as drought continued to impact western portions of the state.

South Dakota State University (SDSU) Extension also provided drought-related information and updates through its Drought Hour webinar series. These were held most Mondays throughout the growing season, from April through October, and focused on both farming and ranching. Topics ranged from drought outlooks to pest management to livestock nutrition.

Webinar recordings were made available on YouTube via NDSU Extension's Ranch Drought Management channel and SDSU Extension's 2021 Drought Hour channel.



◄ Figure 10: NADM Maps at the end of each climatological season in 2021, showing the progression of the drought across the U.S. Northern Plains and Canadian Prairies. Source: NOAA/NCEI, NDMC

SPRING 2021: PRECIPITATION SHIFTS THE EPICENTER OF THE DROUGHT

Spring 2021 began with a large portion of the region in drought. Over the course of the season, conditions eased in areas that picked up precipitation, like portions of central Wyoming, southern Montana, and southwestern South Dakota. Meanwhile, drought expanded and intensified as deficits accrued in other areas, especially across North Dakota, northern South Dakota, eastern Montana, and southern portions of Saskatchewan and Manitoba.

By March 9, 2021, the entire state of North Dakota was experiencing drought conditions (D1–D4) for the first time since the drought of 2012.

Extremely warm and dry conditions in March helped to drive the development of a new area of extreme drought (D3) centered over eastern portions of the region. During this time, evaporative demand increased, soils continued to dry, and streamflows were running below normal to much below normal in some areas. The plains snowpack was largely non-existent and there was an increased risk of wildfire. For Montana and North Dakota, it was the 2nd driest March on record (*Figure 12*). Deficits in North Dakota were especially high, with record-setting dryness at multiple time periods (*Table 1*).

Although temperatures moderated in April, drought expanded as both short-term and long-term precipitation deficits continued to accrue. Generally dry conditions continued into May, and at the end of spring, extreme (D3) and exceptional (D4) drought encompassed about 11% of the U.S. Northern Plains and Canadian Prairies. This area included about 18% of North Dakota, which was a new record for the state. Nearly 65% of Manitoba's agricultural region was also categorized in

►**Figure 11: Stunted grasses exposed cultural sites at the Fort Belknap Indian Reservation. Credit: Dennis Longknife, Fort Belknap Indian Community**

Drought Impacts on Cultural Resources and Practices in the U.S. Northern Plains

With Tribal Nations located throughout the U.S. Northern Plains, local drought impacts varied depending on location. However, many Tribal Nations reported impacts related to agriculture, ecosystems, water resources, and human health. Drought also had an impact on cultural resources and practices. For instance, fire bans implemented by the Standing Rock Sioux Tribe impacted ceremonies that require fire, like sweat lodge ceremonies. Water and fire extinguishers were made available as a precaution.

Impacts like these were shared during the Northern Plains Drought Update & Outlook Tribal Webinar series that ran from late May through early December 2021. These webinars provided timely information about how tribes were responding to drought, current conditions and outlooks, and drought resources available for Tribal Nations in the region. Feedback on the webinars indicated that this balance of information was particularly useful. The series was a collaboration among the USGS North Central Climate Adaptation Science Center, NOAA NIDIS, NOAA National Centers for Environmental Information (NCEI) Regional Climate Services, the High Plains Regional Climate Center, and the USDA Northern Plains Climate Hub.

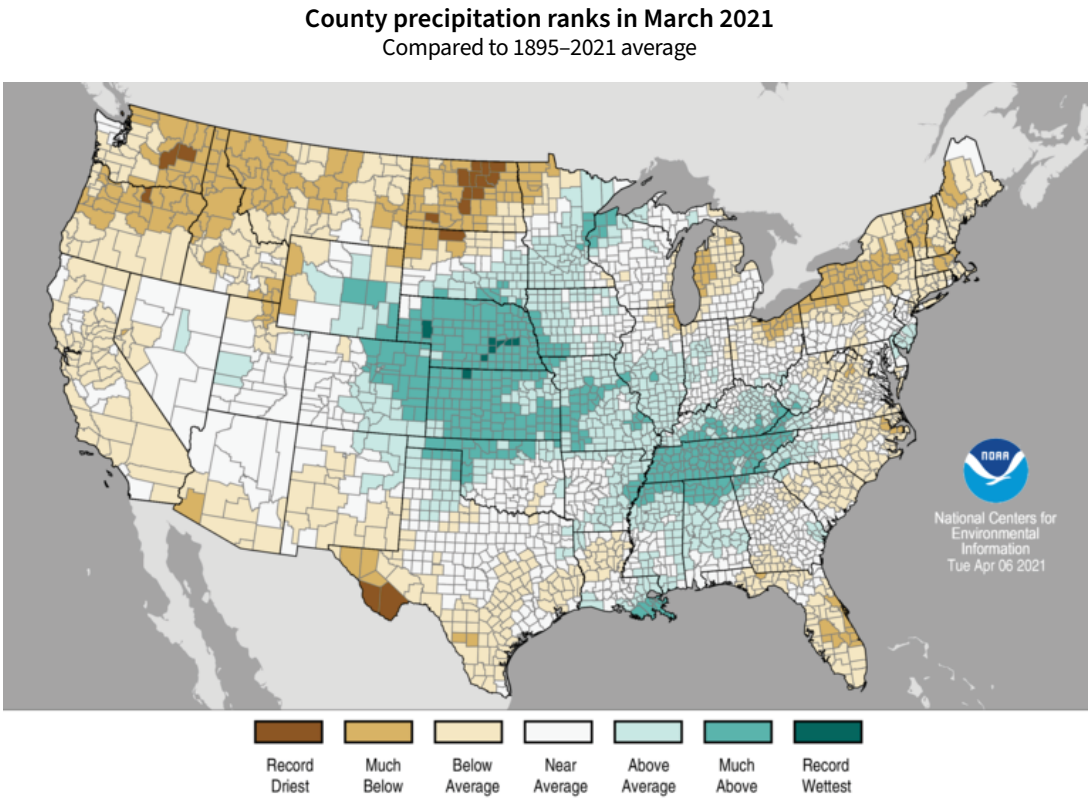
either extreme (D3) or exceptional (D4) drought by the end of May. With drought conditions gradually easing across Wyoming, the most intense drought conditions were now located in the eastern part of the region (*Figure 10*).

Conditions across the U.S. Northern Plains and Canadian Prairies were much worse going into the summer of 2021 than they were going into the summer of 2017.

By the end of the spring season, numerous impacts from the drought had been reported. Dust storms formed in Montana and North Dakota where high winds were able to lift dry, exposed soils. Livestock producers contended with poor pasture and rangeland conditions. In the Dakotas, cattle sales increased due to a lack of forage production, low stock pond levels, and water quality issues. Feed costs and availability were also a factor in the increased sales. Some crops were not faring well, especially in North Dakota (e.g., barley, oats, and spring wheat). Streamflows were below normal or much below normal in many locations. Fires burned across thousands of acres, including parts of Theodore Roosevelt National Park in North Dakota and areas near Mount Rushmore National Monument in South Dakota. In response to worsening conditions, state-level executive orders began to be issued. A state of emergency was declared in South Dakota on March 30, 2021. Shortly thereafter, a statewide wildfire emergency was declared in North Dakota on April 1, followed by a statewide drought disaster declaration on April 8. More information on these executive orders and the overall response may be found on *page 31*.

SUMMER 2021: EXTREME HEAT AMPLIFIES DROUGHT

Over the summer of 2021, record-breaking heat coupled with extremely dry conditions caused drought to expand and intensify even further (*Figure 13*). Multiple heat waves during June and July resulted in average temperatures rivaling or topping some of the most notable drought periods in history. With records going back to 1895, Montana had its hottest June–July on record, beating out the Dust Bowl year of 1936, while Wyoming tied with 1988 for its hottest June–July. Canada experienced unprecedented heat during this time



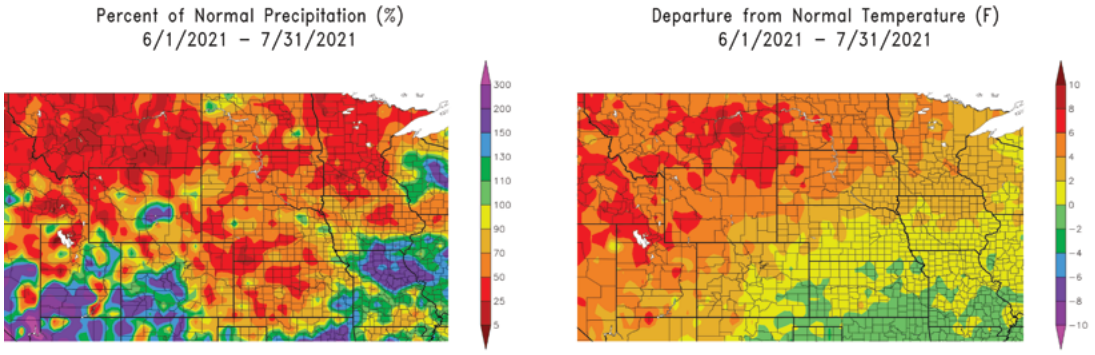
◄ **Figure 12: March 2021 was particularly dry across portions of the U.S. Northern Plains. While it was the 2nd driest March on record for Montana and North Dakota, for some counties in North Dakota and northern South Dakota, it was the driest March on record. Credit: NCEI**

TABLE 1: RECORD-SETTING DRYNESS IN NORTH DAKOTA

Time Period	Precipitation Ranking (127 Years in Record)
1 month (March 2021)	2nd Driest
2 months (February 2021 – March 2021)	Driest
3 months (January 2021 – March 2021)	Driest
4 months (December 2020 – March 2021)	Driest
5 months (November 2020 – March 2021)	Driest
6 months (October 2020 – March 2021)	Driest
7 months (September 2020 – March 2021)	Driest
8 months (August 2020 – March 2021)	Driest

◄ **Table 1: North Dakota experienced record-setting dryness at multiple timescales during the drought (period of record 1895–2021). Data source: NOAA National Centers for Environmental Information, Climate at a Glance (2022b)**

as well, even setting a new all-time record high temperature just outside the region. The heat was accompanied by extremely dry conditions during a critical time for agriculture in the region. For instance, Montana had its driest June–July period on record, while portions of southern Manitoba received only 6% of normal precipitation from early June through mid-August. In response to deteriorating conditions, a statewide drought emergency was declared in Montana in early July. This was quickly followed by a statewide wildland fire emergency.



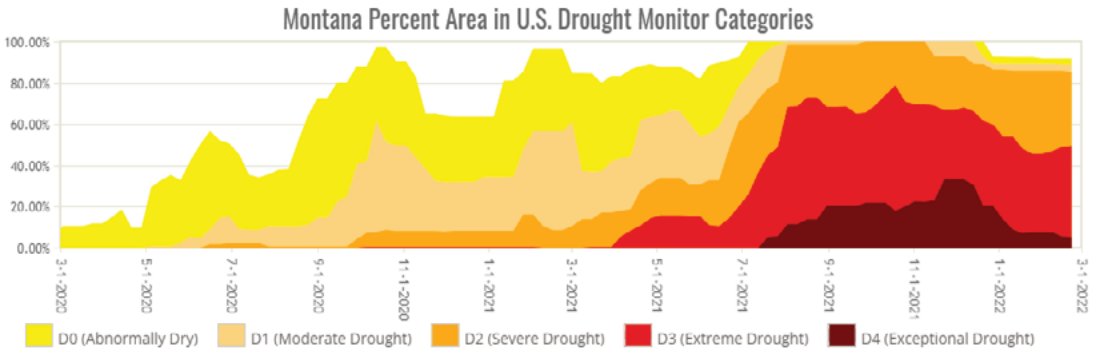
► **Figure 13: June and July 2021 ranked among the driest and warmest June–July time periods on record in the U.S. Northern Plains. Credit: High Plains Regional Climate Center**

By the time rains arrived in August, precipitation deficits were so high and the impacts so far-reaching that few improvements were made. Even with slight improvements to intensity, the footprint of the drought continued to expand in some areas. At the end of summer, drought (D1–D4) encompassed nearly 75% of the region (*Figure 10*). Extreme drought (D3) was widespread and exceptional drought (D4) impacted areas of southern Manitoba, central Saskatchewan, north-central North Dakota, and north-central and southwestern Montana.

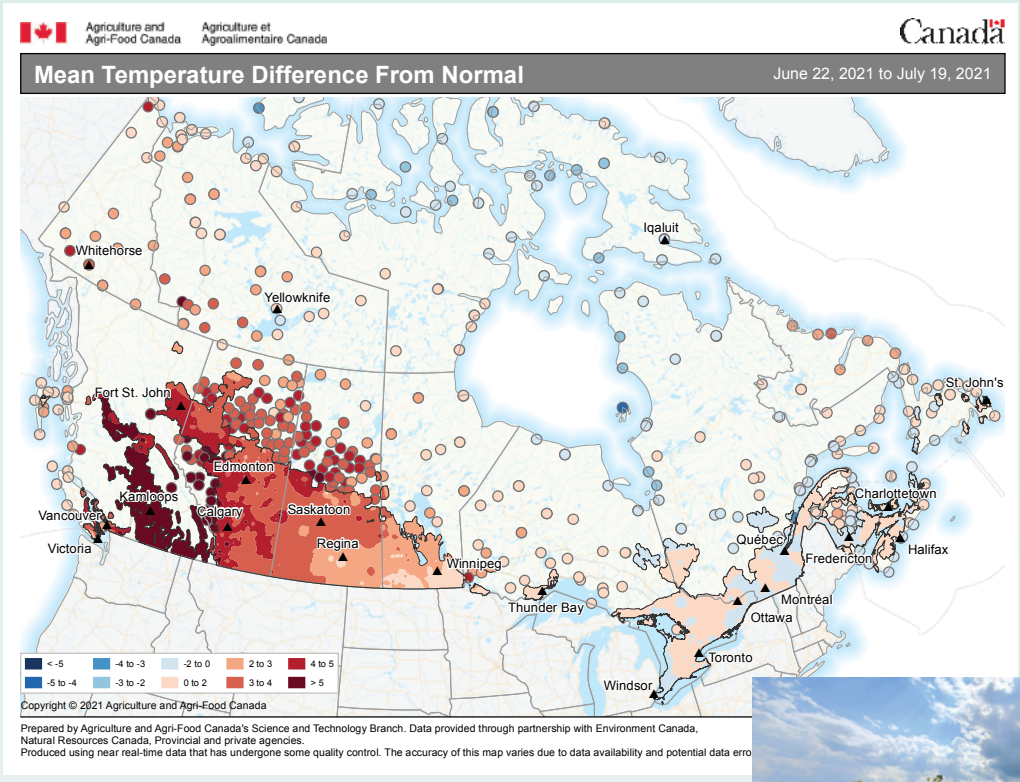
In Canada, the July and August drought assessments depicted the most severe and wide-reaching drought since the inception of the Canadian Drought Monitor in 2002. In fact, 86% of the Prairie region's agricultural areas were considered to be in at least severe drought (D2) or worse by the end of August.

These intense conditions strained the region and caused wide-reaching impacts. Intense heat and low precipitation stunted the growth of crops, pastures, and rangeland. Hay production was down significantly. Cattle competed with grasshoppers for what little forage remained. Many livestock producers hauled water, weaned calves early, and culled herds. Wetlands shrunk. Disease spread through wildlife as they congregated at dwindling water sources. Wildfires burned thousands of acres (*Figure 17*). Hydroelectric power production declined. Longer-term impacts of the drought, especially those to wildlife, ecosystems, and infrastructure, may still be realized for years to come.

For a more comprehensive, detailed listing of impacts, see the *Drought Impact Reporter* and *CMOR-Drought* for the U.S., and the *Agroclimate Impact Reporter* for Canada.



▲ **Figure 14: In Montana, abnormally dry (D0) and drought (D1–D4) conditions built slowly after the start of 2020, with drought fully encompassing the state from late summer of 2021 through the early winter. This included a seven-week stretch starting in late September 2021 where the entire state was in at least severe drought (D2). September 28, 2021 marked the first time in the history of the U.S. Drought Monitor that all of Montana was in at least the D2 designation. Credit: U.S. Drought Monitor**



◄ **Figure 15: Mean temperature difference from normal across Canada for June 22 through July 19, 2021. Credit: Agriculture and Agri-Food Canada**

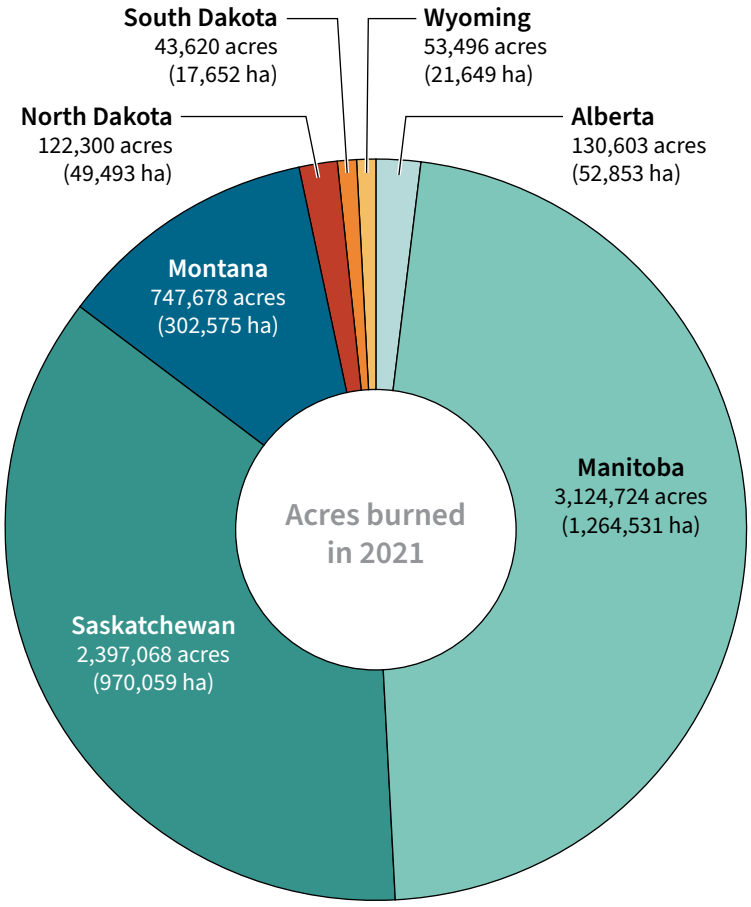
Summer 2021 Heat Wave: Focus on Canada

Several periods of extreme heat impacted the U.S. Northern Plains and Canadian Prairies during the summer of 2021. However, the late June and early July heat wave in the western U.S. and Canada was of historic magnitude. Thousands of records were set during this timeframe, with many locations across the Pacific Northwest, Intermountain West, and Western Canada setting new records for highest all-time maximum temperature. In Canada, the "heat dome" was unprecedented in its intensity, duration, and early-season timing, and stretched from Vancouver Island to Manitoba and into the Northwest Territories at its peak. The intense heat exacerbated drought conditions, especially in British Columbia and the western Prairies.

▲ **Figure 16: Canola crops near Belle Plaine, Saskatchewan show heat blast and stunted growth in July 2021. Credit: Alyssa Klein, Agriculture and Agri-Food Canada**

In Canada, this heat wave produced an all-time record high temperature of 121.3 degrees F (49.6 degrees C) at Lytton, British Columbia on June 29, which was nearly 43.2 degrees F (24.0 degrees C) above normal. The previous national record of 113.0 degrees F (45.0 degrees C) that had stood for 84 years at Yellowgrass and Midale, Saskatchewan was first exceeded on June 27 at Lytton, then again on the 28th and 29th. Six other locations also broke this record, but none recorded temperatures quite as high as Lytton. This new temperature record is higher than any in the U.S. outside of the Desert Southwest, and higher than any temperature ever recorded in Europe or South America. Much of the town of Lytton was destroyed in a fire the day after this record was set.

This heat wave intensified drought and caused significant impacts to agriculture, infrastructure, and public transportation, and resulted in more than 800 deaths in Western Canada. In the Prairie region, the heat wave hit during the critical flowering stage of canola, resulting in heat blast and substantially reducing yield potential. Dry pastures left ranchers with little for their cattle to graze, forcing them to dip into winter feed stocks and consider shrinking their herds by sending cattle, even prized breeding cows, to slaughter. After the heat wave ended, many crops were stunted and matured without filling seed pods.



▲ **Figure 17: Wildfires burned hundreds of thousands of acres across the state of Montana during 2021. Two examples of these fires include the Pine Grove Fire and the Richard Spring Fire. The Pine Grove Fire started on August 17 in the Little Rocky Mountains of Montana. With high winds fanning the flames, the fire spread quickly, causing evacuations of some tribal communities and surrounding towns. Air tankers and heavy equipment were instrumental in slowing the wildfire, and tribal members also fought the wildfire, saving lives. Ultimately, two structures were lost to the blaze. The Richard Spring Fire burned over 170,000 acres in southeastern Montana in the late summer of 2021, and severely impacted parts of the Northern Cheyenne Indian Reservation and Rosebud County. A major disaster declaration for this fire was declared September 30, 2021. Credit: Fiona Martin**

AUTUMN 2021: DROUGHT IMPACTS CONTINUE, DESPITE SOME IMPROVEMENTS; DROUGHT INTENSIFIES IN MONTANA

Changes in drought conditions varied over the course of the autumn 2021 season, with both improvements and degradations. Precipitation largely missed the state of Montana, where drought encompassed the entire state from late summer through early winter (*Figure 14*). Numerous impacts were reported across the state as wildfires continued to burn, pasture and rangeland conditions continued to decline, streamflows dwindled, and vegetation was stressed.

Meanwhile, widespread precipitation across eastern portions of the region, especially North Dakota, South Dakota, and Manitoba, helped improve or remove drought conditions in the short-term, but long-term deficits and impacts remained. With the 2021 growing season coming to an end and harvest activities wrapping up, this precipitation could do little for agriculture in the region. Production and yields were down for many crops. With feed and surface water supplies still in short supply, producers continued to sell off cattle. High levels of stress were also reported among ranchers and other producers.

Even with improvements, drought still impacted approximately 65% of the region at the end of autumn. As the region entered the driest season of the year, it was poised to begin the upcoming growing season locked in drought.

WINTER 2021–2022 AND BEYOND: DROUGHT CONTINUED INTO 2022

Drought conditions changed significantly after the autumn of 2021, as precipitation over the winter and spring led to widespread improvements. Heavy precipitation in April 2022 even led to flooding in parts of Manitoba and North Dakota. At the end of May 2022, both Manitoba and North Dakota were free of drought. Drought persisted, however, across southern portions of Alberta, southwestern Saskatchewan, western and southern portions of South Dakota, and the majority of Montana and Wyoming.

Over the summer months, overall drought conditions improved, with only localized pockets of drought development or intensification. According to NOAA's Climate Prediction Center, as of mid-August 2022, remaining drought conditions were likely to persist across the U.S. Northern Plains through the end of autumn. Development was also likely in portions of eastern Montana and western North Dakota. For the most up-to-date information on drought conditions in your area, visit the U.S. Drought Portal (*https://www.drought.gov/*). □

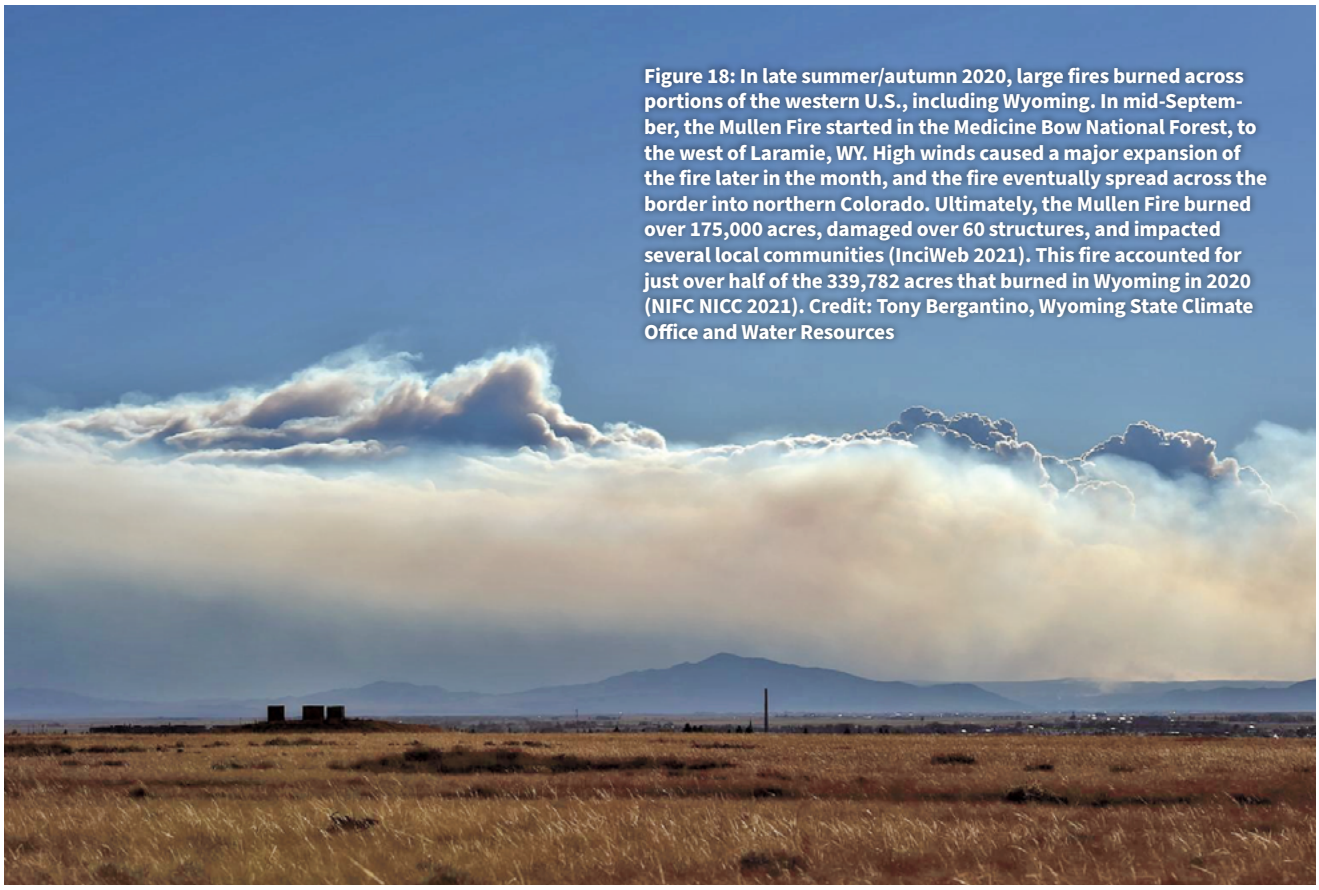


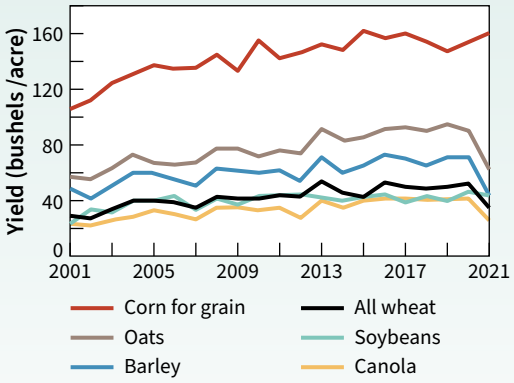
Figure 18: In late summer/autumn 2020, large fires burned across portions of the western U.S., including Wyoming. In mid-September, the Mullen Fire started in the Medicine Bow National Forest, to the west of Laramie, WY. High winds caused a major expansion of the fire later in the month, and the fire eventually spread across the border into northern Colorado. Ultimately, the Mullen Fire burned over 175,000 acres, damaged over 60 structures, and impacted several local communities (InciWeb 2021). This fire accounted for just over half of the 339,782 acres that burned in Wyoming in 2020 (NIFC NICC 2021). Credit: Tony Bergantino, Wyoming State Climate Office and Water Resources

Impacts on Crops

Large reductions in production in 2021 were estimated in North Dakota where durum wheat production was down 44%, sunflower production was down 43%, and canola was down 21% compared to 2020. Although down, production of canola in 2021 was still one of the largest on record for North Dakota. Canola production was also down in Saskatchewan by 43%, while yields were down by 28% in Manitoba. Additionally, wheat yields dropped by 43% in Saskatchewan and 22% in Manitoba. South Dakota, which led all states in sunflower production in 2020, was estimated to have a 30% reduction in sunflower production in 2021. Barley production in South Dakota and oat production in Montana were estimated at record lows. Safflower yields were at record lows in Montana as well. Interestingly, corn and soybean acres planted were up compared to 2020 in the Dakotas, but yields were down. Lingering wet conditions were an issue in 2020.

Data from the Crop Production 2021 Summary from USDA's National Agricultural Statistics Service (2022) and Statistics Canada (2021).

◄ Figure 19: This image from Foster County, North Dakota, shows poor germination of crops in June 2021. Credit: NDSU Extension



◄ Figure 20: Nationally, in Canada, yields of certain crops were impacted by drought in the Canadian Prairies. Credit: Stats Canada

Figure 21: Geese with goslings stranded in a dry wetland near Havre, Montana on August 30, 2021. Credit: Michael Downey, Montana Department of Natural Resources and Conservation

Drought Impacts to Ecosystems and Wildlife

Numerous drought impacts to ecosystems and wildlife were reported around the region in 2021. While the long-term impacts of the drought have not been realized, short-term examples included:

The combination of drought and high heat was a concern for fish populations as streamflows declined and water temperatures increased. In response to drought conditions in 2021, fisheries managers across Montana implemented 32 fishing closures across 17 rivers related to low streamflows and high water temperatures (Montana Fish, Wildlife and Parks 2021). Full closures or afternoon closures to avoid fishing under the most stressful conditions (hoot-owl restrictions) were enacted when in-stream conditions exceeded predetermined thresholds as specified in proactive drought plans developed for many major rivers by Montana Fish, Wildlife and Parks. The overall extent of drought-related fishing closures in the summer of 2021 were among the highest years recorded since 2014 (Montana Fish, Wildlife and Parks 2021).

Outbreaks of epizootic hemorrhagic disease (EHD) were reported, particularly across eastern portions of Montana and Wyoming, and western portions of the Dakotas. EHD is common during times of drought, as animals, such as white-tailed deer and pronghorn antelope, congregate around dwindling water resources. Hunters in both North Dakota and South Dakota could request refunds on hunting licenses due to the outbreak's impact on white-tailed deer populations. Reduced cover and poor forage conditions due to the drought may have also impacted pronghorn fawn survival rates across the region.

Habitats for waterfowl and upland birds were impacted by the drought, with declining wetland conditions and reduced cover impacting breeding and nesting areas. Wetlands were particularly impacted by drought, especially in the Prairie Pothole region of the Dakotas. The North Dakota Game and Fish Department reported that the May 2021 water index, which is a measure of the number of wetlands holding water, was down 80% from the previous year. This marked the largest decline since the survey started in 1948. A unique impact was reported from the Fort Belknap Indian Reservation in Montana, where the absence of grassland birds' chirping was noted.

Drought and the Upper Missouri River

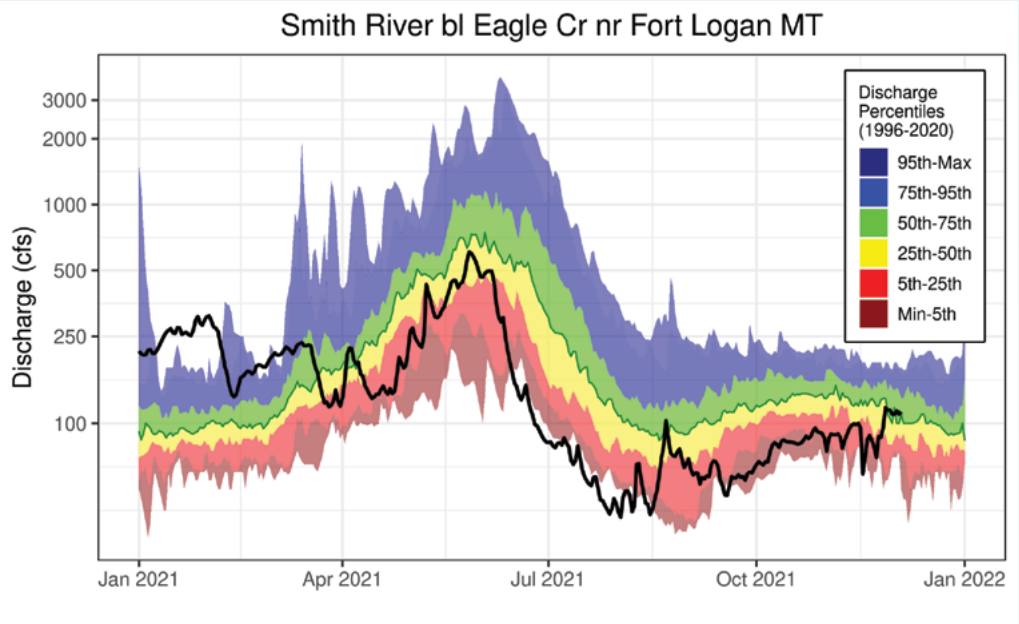
In a dramatic shift from wet to dry conditions, the runoff in the upper Missouri River Basin went from 2nd highest in 2019 to 10th lowest in 2021.

At the start of 2020, the Missouri River Basin had just recorded its second highest calendar year runoff on record (2019: 60.9 million acre-feet above Sioux City, IA). Soils were wet and there was an increased potential for flooding. Although conditions had turned drier in the first part of the year, runoff was still above average due to saturated soils. As drought developed and spread across upper parts of the Basin, runoff declined and inflows into the reservoirs were much lower than normal, especially in the late summer and early autumn. Despite lower runoff later in the year, the annual runoff for the Missouri Basin (above Sioux City, IA) was 31.1 million acre-feet, which was 121% of average.

Conditions going into 2021 were quite different from the year prior. Soils were dry and much of the Basin was impacted by drought at the start of the year. Below-normal precipitation, a nearly non-existent plains snowpack, and below-average mountain snowpack all contributed to reduced runoff and reservoir inflows. Extremely warm conditions led to a rapid melt-out of the mountain snowpack by mid to late June, which was several weeks earlier than usual. In July, water conservation measures were implemented by the U.S. Army Corps of Engineers, which slightly reduced flows for navigation from Gavins Point. As the year went on, runoff continued to be below average, despite precipitation picking up again. Even heavier precipitation events produced little runoff for lakes, rivers, and streams due to dry soils. Ultimately, the annual runoff for the upper Missouri River Basin was 15.2 million acre-feet, which was the 10th lowest on record.

Lower reservoir levels did have some impacts across the region by reducing hydroelectric power generation and limiting access to boat ramps. Some irrigators also reported water intake issues. The National Weather Service Missouri Basin River Forecast Center also issued low-flow forecasts in support of power plant cooling water intake in the Sidney reach of the Yellowstone River from autumn of 2020 through winter of 2021.

Runoff data obtained from the U.S. Army Corps of Engineers.



◄ Figure 22: USGS streamflow for the Smith River below Eagle Creek near Fort Logan in Montana. 2021 flows (black line) are compared to historical flow percentiles calculated using the period of record (1996–2020). Record low flows were observed for nearly two months starting June 16, 2021. Credit: Montana Climate Office

With pasture and rangeland conditions in decline, ranchers were forced to begin feeding hay to their livestock earlier than usual. Hay production was also impacted by the drought, and feed supplies were limited and expensive.

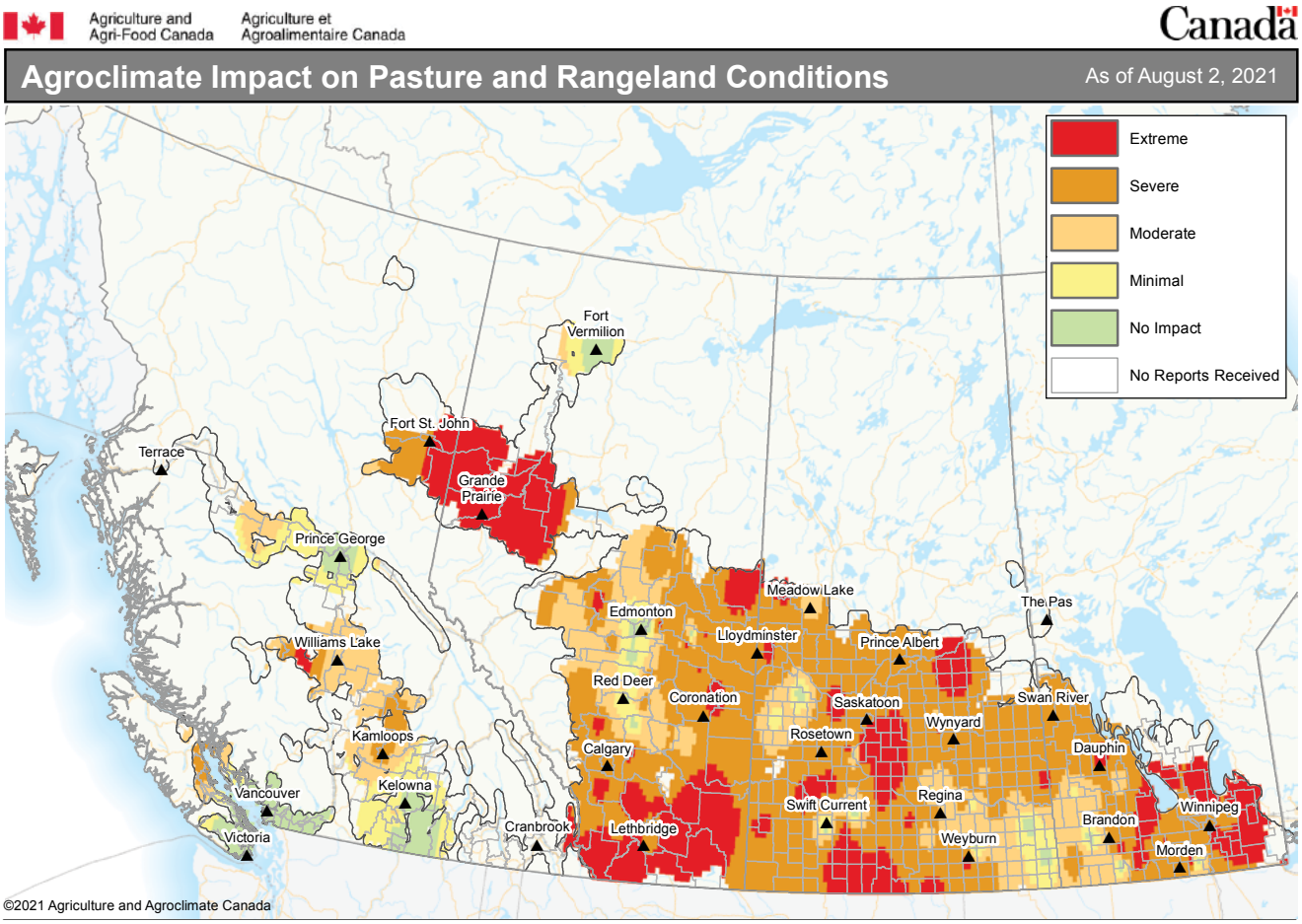
Figure 23: Cows waiting to be fed in farmlands of Montana. Credit: Handcraft Films

FOCUS ON THE LIVESTOCK INDUSTRY: IMPACTS & RESPONSES

During the 2020–2021 drought, a combination of factors led to impacts in the cattle industry, with cattle inventories declining by about 5–10% across the region in 2021 alone. On the local level, herds were reduced significantly and there were some reports of producers selling entire herds in Manitoba and North Dakota. Canadian cattle inventories were at their lowest since 1989 (Statistics Canada 2022). While destocking of herds is a normal drought mitigation strategy, it can take several years to build herds back up again, meaning that the economic impacts of the destocking of 2021 could extend for years to come.

PASTURE AND RANGELAND

Pasture and rangeland were severely impacted during the drought of 2021. Conditions leading up to 2021 contributed to the severity of this impact. For instance, the dry conditions in the fall of 2020 resulted in high tiller mortality of cool-season grasses. In the Dakotas, a 20% reduction in pasture, rangeland, and hay production was projected due to 2020 drought impacts alone. In addition to extremely dry conditions, temperatures during the late spring and summer of 2021 played a role in the steep decline in pasture and rangeland conditions across the region. In April and May, temperatures across much of the region were near normal to slightly below normal. This cooler period was immediately followed by an early, intense heat wave in June where temperatures soared, in some cases over 100.0 degrees F (37.8 degrees C). This rapid transition from cool to extremely hot conditions shortened the



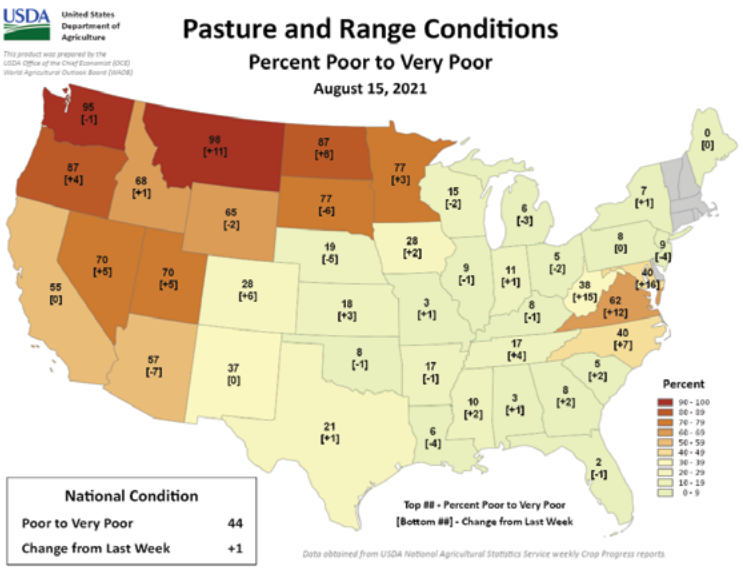
▲ **Figure 24: Producers rated impacts to pasture and rangeland conditions as severe to extreme across much of the Canadian Prairies.**

growing period and stressed the vegetation. In combination with the drought, this switch in temperatures had an impact all season long. Evaluations conducted by NDSU Extension found 50–75% reductions in pasture, rangeland, and hay production were common across the state, with even greater losses reported in areas of exceptional drought (D4). Even when rainfall came later in the season, it was too late to improve pasture and rangeland conditions for most areas. In addition, lands that were overgrazed during the 2021 grazing season will impact the quantity and quality of pasture and rangeland in the upcoming season.

FORAGE AND HAY PRODUCTION

The drought also negatively impacted forage and hay growth. Overall, hay yields were down up to 50% in Canada, with some producers only getting 10–25% of their usual hay production. Meanwhile, alfalfa hay production was down at least 30% in each of the U.S. Northern

▼ **Figure 25: At various times during the summer and autumn 2021, a large proportion of the pasture and rangeland in the U.S. Northern Plains were rated in poor or very poor condition. Credit: USDA**



► **Figure 26: Many tribal ranchers and land managers also faced challenges with pasture and rangeland quality, forage and hay production, water supplies, and pests. Here, variable rangeland conditions are shown in a buffalo pasture at the Fort Belknap Indian Reservation. Credit: Dennis Longknife, Fort Belknap Indian Community**

Plains states. In North Dakota, production was down 62% from 2020 and in Montana, production was the lowest since 1988, another historic drought year (USDA NASS 2022, USDA NASS Montana Field Office 2022).

Due to the limited hay production, ranchers often had to look elsewhere for feed supplies. Producers in need of hay could be connected to hay sellers/donors through various online platforms. Examples include the Montana Department of Agriculture Hay Hotline and the SDSU Extension Feed & Forage Finder Facebook group. In North Dakota, the 2017 Drought Hotline and Interactive Hay Map were reactivated in April of 2021. In Canada, producers were connected through the Hay West 2021 Initiative, which managed approximately 150 shipments (5.6 million pounds) of hay to farmers in need. In an effort to facilitate the transport of hay, some transportation restrictions were waived as well. Many livestock producers harvested failed crops and non-traditional forages (e.g., cattails) for livestock feed due to forage shortages in the region. An additional concern was nitrate poisoning as drought-stressed crops that accumulate nitrogen can lead to nitrate toxicity when fed to cattle.

WATER SUPPLIES

Providing adequate water supplies for livestock was an issue for many ranchers as surface water supplies dwindled due to the drought. In some areas, like Wyoming, local ranchers reported that historically reliable water sources, such as stock ponds, creeks, and beaver ponds, had gone dry for the first time in memory. Even in areas where grasses were in relatively good shape, surface water was often in short supply. Subsequently, many ranchers were forced to haul water to their herds, which can be an expensive, logistically challenging endeavor. Some federal, state, and provincial programs were available to help producers with water supply issues. For instance, North Dakota's Drought Disaster Livestock Water Supply Assistance Program was reactivated in April 2021. As of mid-December, over $5.6 million in financial assistance had been approved for eligible producers implementing new water supply projects (Office of the Governor, State of North Dakota 2021). Ag Action Manitoba also provided $2.4 million in funding to livestock producers for water resource development through its Beneficial Management Practice 503 program (Managing Livestock Access to Riparian Areas).

◄ **Figure 27: Dry water hole in Ward County, North Dakota in October 2021. Credit: NDSU Extension**

▲ **Figure 28: Grasshopper on barley in Canada. Credit: Amelia Martin**

Poor water quality was also reported around the region. As water levels drop, the concentration of dissolved salts and minerals increases, often leading to poor water quality. Testing can help to identify water sources with poor quality, and can support management decisions, such as moving herds. Extension agents from both SDSU and NDSU noted an increase in testing in 2021 due to the drought (North Central Region Water Network 2021, NDSU 2021a). In Saskatchewan, nearly half of farm-based water supplies were unusable or in poor condition at the end of July 2021. There was also an increase in cyanobacteria blooms observed on lakes, reservoirs, and ponds, leading to potential cyanobacteria poisoning in livestock. Due to the high risk of mortality when livestock consume cyanobacteria many ranchers excluded livestock from pastures with active blooms, regardless of available forage levels.

GRASSHOPPERS AND BLISTER BEETLES

Scarce feed and water supplies were not the only challenges ranchers had to contend with during the drought. Grasshoppers were a major issue across the region, in both 2020 and 2021, with some pastures and crops being stripped bare as the insects sought out food sources. In response to the outbreak, the USDA's Animal and Plant Health Inspection Service (APHIS) provided treatments to reduce grasshopper populations in several western states, including Montana and Wyoming (USDA APHIS 2021). Blister beetles, which often accompany high grasshopper populations, were also a concern as they are toxic to cattle and horses, if eaten in hay (NDSU 2021b).

ASSISTANCE FOR LIVESTOCK PRODUCERS

Many programs are designed to assist livestock producers before, during, and after times of drought. Below are just some of the ways that the U.S. and Canadian governments provided assistance to livestock producers during this drought.

Examples from the United States:

- Preliminary data indicate that the USDA Livestock Forage Disaster Program (LFP) provided nearly $280 million in assistance to eligible producers in the U.S. Northern Plains states during

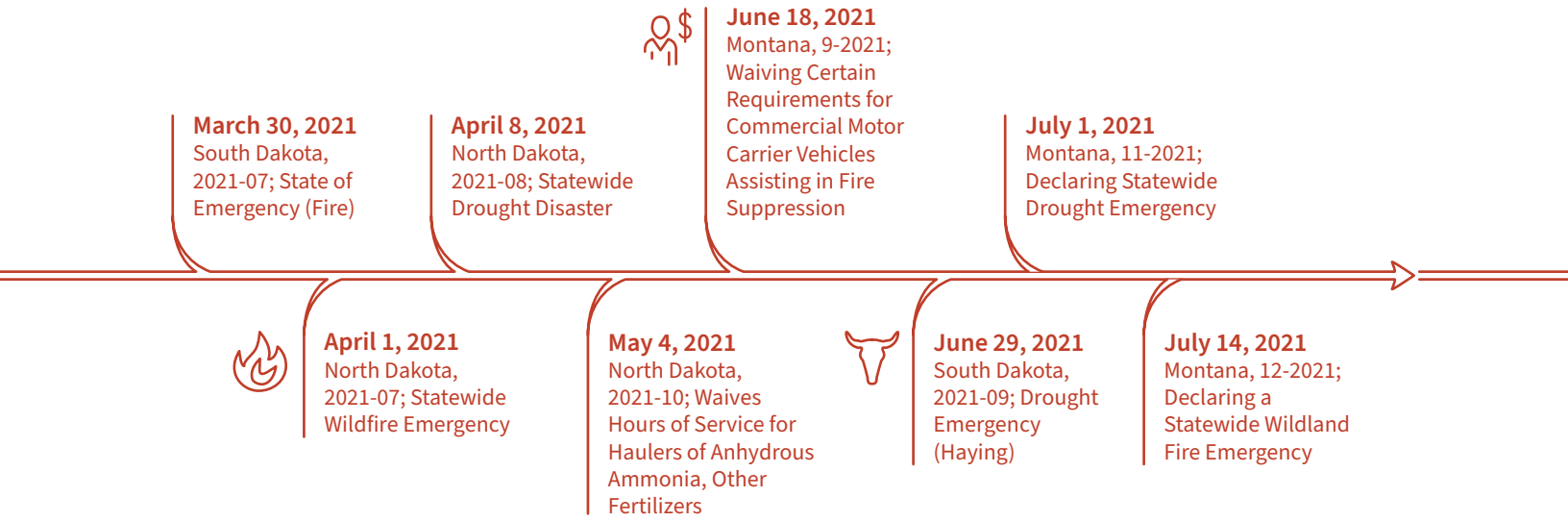
► **Figure 29: Grazing allotment near Battle Mountain, Wyoming in August 2021. Credit: Dannele Peck, USDA Northern Plains Climate Hub**

2021. (Data subject to change as additional paperwork is processed.)

- The USDA Emergency Assistance for Livestock, Honey Bees and Farm-raised Fish Program (ELAP) expanded their program in 2021 to help offset the costs associated with transporting feed for grazed livestock. A new tool, the ELAP Feed Transportation Producer Tool, was developed to help ranchers document and estimate these payments.
- All counties in the U.S. Northern Plains states were, at some point, eligible for emergency haying and grazing of USDA Conservation Reserve Program (CRP) lands during the drought.
- In the fall of 2021, it was announced that the Extending Government Funding and Delivering Emergency Assistance Act would provide $750 million in assistance to livestock producers who were impacted by drought or wildfire in 2021.

Examples from Canada:

- Up to $825 million in cost-shared AgriRecovery funding was made available by the Government of Canada, along with the governments of Alberta, British Columbia, Manitoba, Ontario, and Saskatchewan. According to Agriculture and Agri-Food Canada, this funding helped thousands of livestock producers cover the extraordinary costs they faced during the 2021 drought, such as obtaining livestock feed, transportation, and water. These governments also agreed to increased interim benefit payments through the 2021 AgriStability Program.
- The Livestock Tax Deferral provision provided assistance to eligible livestock producers who were forced to sell a significant portion of their breeding herd due to drought.
- Adjustments to the AgriInsurance program allowed for drought-stricken crops to be utilized as feed sources in the Prairie provinces.
- In 2021, Crown lands that were not usually designated for agricultural use were temporarily available for haying due to the drought. □



▲ **Figure 30: Timeline of Executive Orders. Credit: NIDIS, Fiona Martin**

SUMMARY OF RESPONSE

EXECUTIVE ORDERS

In 2021, 17 drought-related executive orders were signed by the governors in the U.S. Northern Plains states, including 4 in Montana, 6 in North Dakota, 4 in South Dakota, and 3 in Wyoming (*Figure 30*). Full text of these executive orders may be found on official state government websites.

AGRICULTURE

Numerous programs provided support to farmers and producers in the U.S. and Canada. While many programs are mentioned in the Focus on Livestock Industry section, more complete listings of national programs may be found at the following websites:

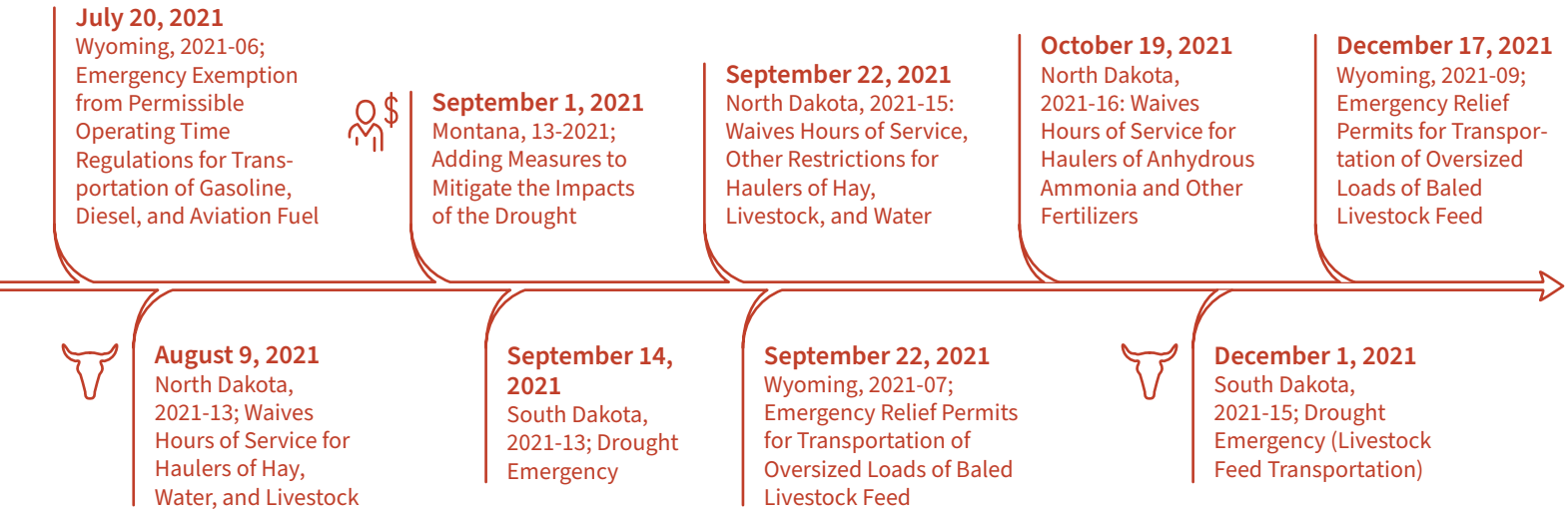
- *USDA Disaster Assistance Programs at a Glance*
- *Agriculture and Agri-Food Canada Programs and Services*

WATER SUPPLY

Several communities across the region implemented voluntary, and in some cases mandatory, water restrictions at various times during the drought. For example, the city of Polson, Montana, located on the Flathead Indian Reservation, declared a water emergency in July, implementing water restrictions and shutting off water to 60 homes. Some of the largest cities in Montana, like Billings, Bozeman, and Helena, also implemented restrictions over the summer of 2021. In Manitoba, some communities reduced water use by 25–30%. Several communities in Canada worked with the Water Security Agency to develop Hydrologic Drought Preparedness Plans.

WILDFIRE

Millions of acres throughout the region burned during the drought of 2020–2021, forcing evacuations, destroying homes, closing timberland areas, and reducing air quality. 2021 was an especially active year, not just in this region, but all across the western U.S. and Canada. Due to the high number of fires, both countries were at a National Preparedness Level of 5, the highest level, for a period of time. At this preparedness level, multiple regions are experiencing complex wildland fire incidents that can create a heavy burden on firefighting assets and stretch resources thin. For places like Manitoba, it was the worst fire season since 1989, another historic drought year.



▲ **Figure 30: Timeline of Executive Orders (cont.). Credit: NIDIS, Fiona Martin**

Response to these fires occurred at all levels from local volunteer firefighters to coordinated federal and international efforts. Burn bans or restrictions were issued in many communities, counties, and on tribal lands at various times during the drought in response to increased wildfire risk. Numerous federal agencies, such as the Bureau of Indian Affairs (BIA), U.S. Forest Service (USFS), and the National Park Service (NPS), responded to the fires. In some instances, international partners also helped provide firefighting support and equipment; however, some were unable to provide assistance due to restrictions related to the COVID-19 pandemic (Canadian Wildland Fire Information System 2021).

CONVENING OF PARTNERS

NIDIS played an integral role in convening federal and statewide partners in the region. For instance, in July 2021, NIDIS partnered with the Federal Emergency Management Agency (FEMA) to increase federal interagency coordination on drought response through a meeting of federal partners, giving updates on support and services available to partners and stakeholders in the region. This included documenting available resources and creating a contact list to increase information-sharing moving forward. NIDIS also held a virtual meeting of state partners working on drought monitoring and response to discuss current conditions and needs in July. This resulted in monthly informal brown bag gatherings where partners could discuss response activities, outreach and communication efforts, as well as best practices and lessons learned. At the end of 2021, the High Plains Regional Climate Center held the 2021 High Plains/Missouri River Basin Drought and Water Resources Workshop, which brought together regional partners to discuss the impacts of the drought, preparedness and response, and gaps and needs. Various groups, including but not limited to Tribal Councils, state agencies, and university Extension, met throughout the drought to discuss local impacts and response as well.

In addition, monitoring teams helped provide robust recommendations to the U.S. and Canadian Drought Monitor authors. Increased collaboration and coordination among partners and agencies also allowed for cross-jurisdictional drought monitoring and firefighting efforts.

DISSEMINATION OF DROUGHT INFORMATION

Throughout the drought, webinars and briefings provided updates on drought conditions, available resources, and/or response strategies. Webinars were often in collaboration with local, state, tribal, federal, and academic partners. University Extension played a key role in

webinar development across the U.S. Northern Plains. Examples of webinars included: NDSU Extension's Navigating Drought on Your Ranch, SDSU Extension's Drought Hour, Montana State University Extension's 2021 Drought Series, and the WCMT Webinar series (see *pages 15 and 16* for more information). The Northern Plains Drought Update & Outlook Tribal Webinar series, a collaboration among the USGS North Central Climate Adaptation Science Center, NOAA NIDIS, NOAA National Centers for Environmental Information (NCEI) Regional Climate Services, the High Plains Regional Climate Center, and the USDA Northern Plains Climate Hub, provided timely information about how tribes were responding to drought, current conditions and outlooks, and drought resources available specifically for Tribal Nations in the region (see *page 18* for more information). Finally, the ongoing North Central U.S. Climate and Drought Summary and Outlook webinar series, which is a partnership with the NOAA Central Region Regional Climate Services Director, the USDA Midwest Climate Hub, the American Association of State Climatologists, and other regional climate partners, provided two special webinars focused on drought, in addition to their usual, monthly occurrences.

Drought information was also provided through various summaries and briefings. For example, NIDIS, along with other federal partners, produced several Drought Early Warning and Drought Status Updates to provide up-to-date drought information to the region throughout the drought (see *page 14* for more information). The National Weather Service also coordinated with federal partners to produce seasonal Hazard Outlooks. And, the High Plains Regional Climate Center continued to produce ongoing monthly and quarterly summaries for the High Plains and Missouri Basin regions, which included an overview of drought conditions.

BROADER EFFORTS

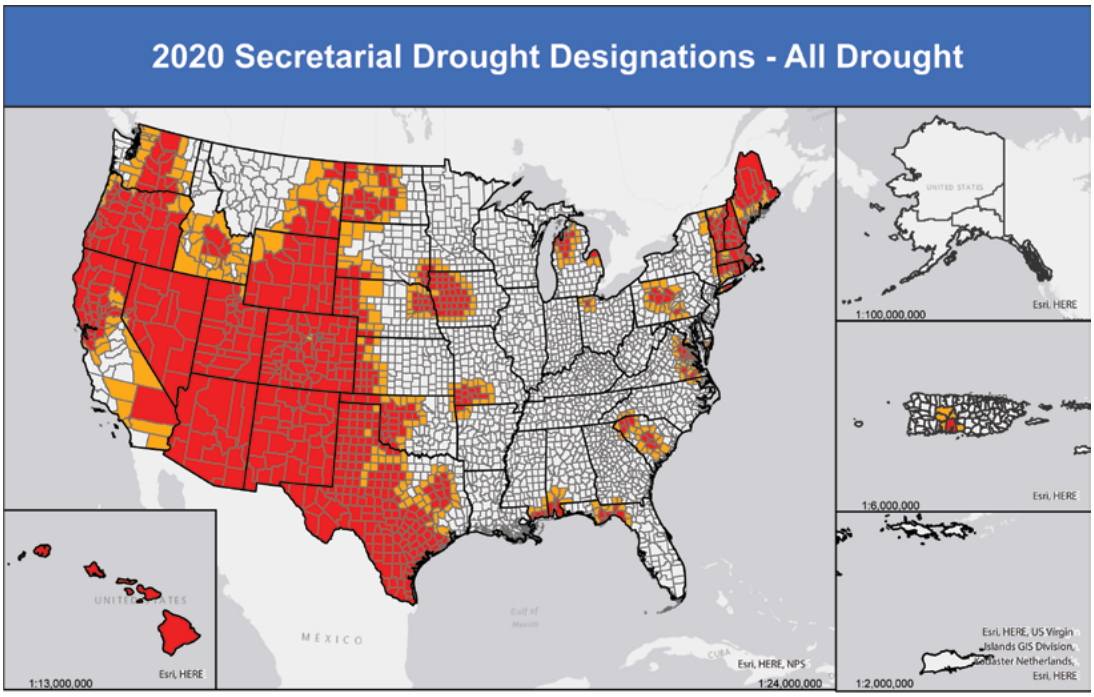
As drought was widespread throughout the western U.S., many efforts included a broader region. For instance, in July 2021, NIDIS held a Western Drought Webinar, which provided information on the current status of the drought, ongoing and potential impacts, and outlook information. Government response and relief efforts were also highlighted. Also in July, NIDIS produced a Western Drought Status Update, which provided timely drought-related information specifically for the western U.S., including Montana and Wyoming. In August, governors from several western states, including Montana and North Dakota, signed a bipartisan letter requesting a FEMA drought disaster declaration. This request was ultimately denied.

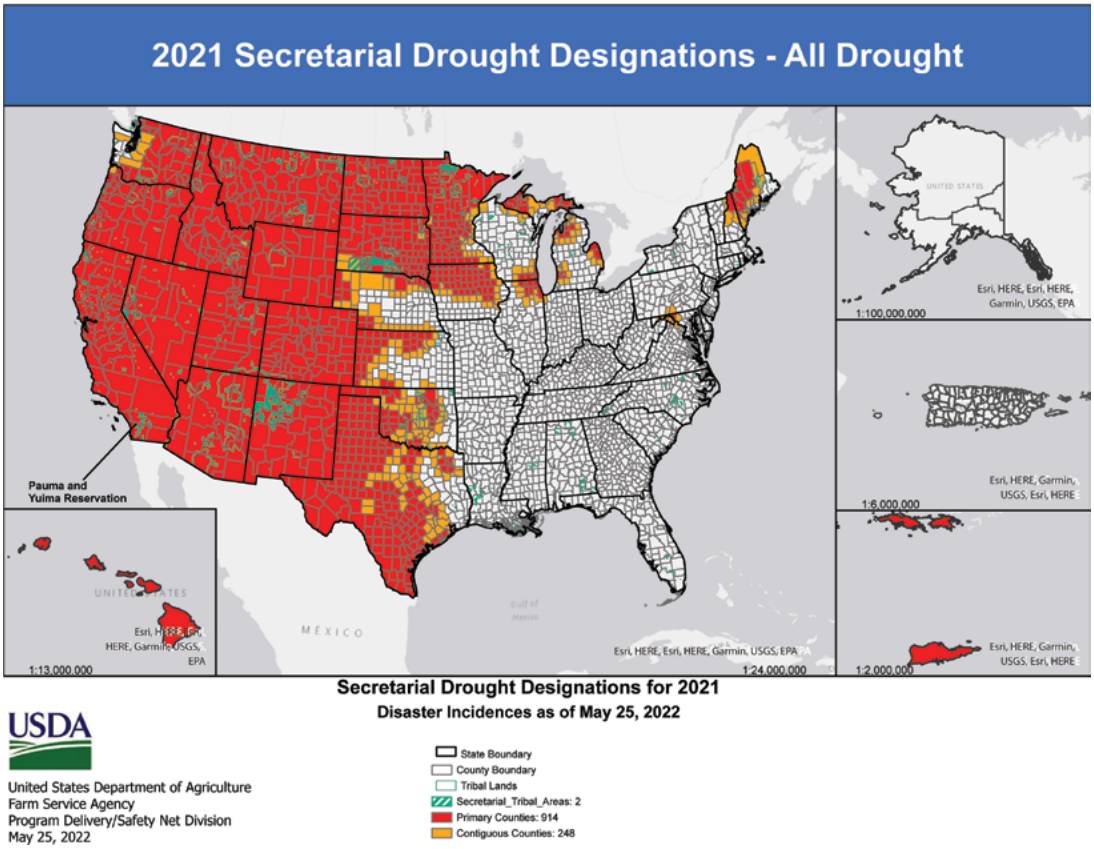
OTHER ASSISTANCE

A number of federal agencies in the U.S. provide ongoing funding for drought-related planning and preparedness efforts. Examples include, but are not limited to:

- NOAA NIDIS: Coping with Drought Research Competition
- U.S. Department of Homeland Security, FEMA: Building Resilient Infrastructure and Communities (BRIC) program, Hazard Mitigation Grant Program
- U.S. Department of the Interior, BIA: Tribal Climate Resilience Program
- U.S. Department of the Interior, Bureau of Reclamation: WaterSMART Drought Response Program

Program specifics and eligibility requirements may be found on program websites. □





▶ **Figure 31: USDA Secretarial Drought Designations allow access to various federal assistance programs through the USDA's Farm Service Agency. Credit: USDA Farm Service Agency**

Impacts on Mental and Behavioral Health in North Dakota

◄ **Figure 32:** **A farmer surveys a drought-damaged corn field. Credit: xfilephotos**

Farming and ranching, the bedrock economic drivers in many rural communities, is stressful even in the best of times. Financial worries, unpredictable commodity prices, plant pests, and isolation all contribute to stress experienced by agricultural producers and others working in agriculture. During 2021, the agricultural sector in North Dakota was heavily impacted by weather-related stress factors, most particularly due to drought conditions, and this in turn significantly affected the mental and behavioral health of many working in agriculture. Stress-related impacts due to drought conditions included:

- Increased financial stresses on farm and ranch operations resulted in heightened individual stress related to increased farm debt and input costs, difficulties in meeting family expenses, and concerns about remaining in business.
- Heightened rates of mental and emotional health difficulties among those working in agriculture, particularly with increased depression, anxiety, and hopelessness about ability to manage or overcome drought conditions.
- Increased rates of substance misuse among agricultural workers, including misuse of alcohol and prescription drug medications, as well as opioid use issues.
- Elevated patterns of social isolation and coping difficulty with challenging conditions, resulting in increased suicidal ideation, suicide attempts and deaths by suicide among agricultural populations.
- Overall negative effects on physical and mental health, relationships and general well-being of those working in agriculture.

In turn, such conditions placed the larger agricultural system at risk and threatened the consistent provision of food, fiber, and fuel that citizens and communities depend on every day for their well-being.

Impacts like these were not limited to North Dakota, and several programs were available to help support mental health needs across the region. New initiatives included:

- The Wyoming Department of Agriculture applied for and received a USDA National Institute of Food and Agriculture (NIFA) grant in 2021 to fund activities that help to address agricultural producers' stress and suicide prevention. This project has three components, which includes creating a pilot project to provide mental health counseling vouchers for individuals in need of those services.
- In early 2022, an Agriculture Behavioral Health Voucher Program, which helps provide access to mental health services, was launched in South Dakota by SDSU Extension, the South Dakota Department of Social Services, and the South Dakota Department of Agriculture and Natural Resources.

Implementing the Manitoba Drought Management Strategy

During the drought, the Manitoba Government followed their Drought Management Strategy, which was developed approximately 10 years ago. The purpose of the Manitoba Drought Management Strategy is to provide a framework for an integrated approach to managing drought, with the goal of minimizing the environmental, social, and economic impacts of drought on Manitoba's residents, economy, and environmental resources. Some of the management strategies developed in this plan and used throughout the 2021 drought included:

- Effective communication and cooperation with both internal and external stakeholders and government departments, including the establishment of drought and water supply committees prior to the drought itself. This also included communication with upstream neighbors to ensure adequate management of low flows.
- Access to timely and accurate drought monitoring data and information, which included the use of both provincial and federal monitoring networks.
- Program implementation, by which several programs were made available to producers who were experiencing extraordinary circumstances due to the 2021 drought. This included both provincial and federally available programs (e.g., AgriRecovery, Herd Management Drought Assistance program, Livestock Feed and Transportation Drought Assistance program, etc.).
- Finally, conservation and appropriation efforts went into play in 2021. This included implementing voluntary or mandatory conservation measures, as well as requests to upstream irrigators to temporarily reduce or cease pumping to allow water supplies for domestic, agricultural, and municipal users to replenish supplies.

Figure 33: Sunrise over Theodore Roosevelt National Park, North Dakota. Credit: Zak Zeinert

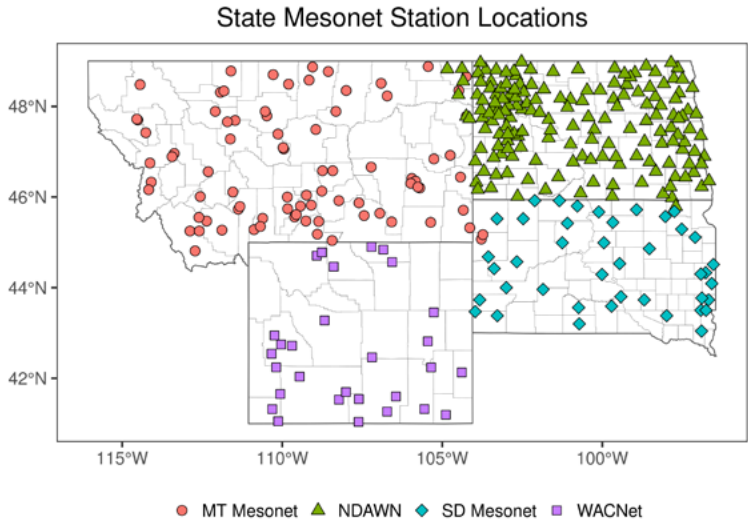
BUILDING RESILIENCE: IDENTIFYING & ADDRESSING GAPS & NEEDS

2020 and 2021 will be remembered for intense drought in the U.S. Northern Plains and Canadian Prairies; whether 2022 will be added to this list remains to be seen. While impacts reached far and wide, overall, the region was better prepared to respond to the drought because of actions that were taken during and after the flash drought of 2017. As researchers and practitioners work together to address outstanding gaps and needs, the region will continue to build resilience into the future.

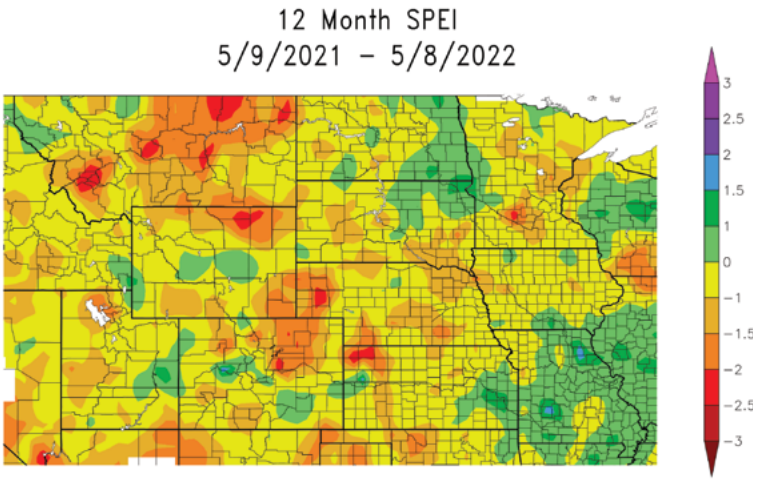
Through a series of partner engagements, NIDIS and partners documented the lessons learned and outstanding needs associated with the drought of 2020–2021. This input has been aggregated and synthesized around the five components of drought early warning, which are outlined below. Synergies with identified gaps and needs during the flash drought of 2017 are noted, where applicable.

OBSERVATION AND MONITORING

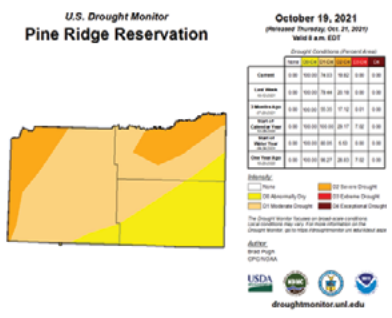
The backbone of drought monitoring is data. Observational data from the atmosphere, the soils, and water resources are critical for drought early warning and response, as well as for planning and preparedness. The need to maintain and invest in current monitoring networks, while also deploying new and expanded networks, was highlighted during the 2017 drought (Jencso et al. 2019). Existing networks, especially those with long periods of record, provide the data needed for developing historical context for droughts. New or expanded networks can help fill gaps where



▲ **Figure 34: This map shows the locations of state mesonet stations in the U.S. Northern Plains as of 2022. Mesonets include the Montana Mesonet, the North Dakota Agricultural Weather Network (NDAWN), the South Dakota Mesonet, and the Wyoming Agricultural and Climate Network (WACNet). Credit: Montana Climate Office**



▲ **Figure 35: New Tools Available for Drought Monitoring: Standardized Precipitation Evapotranspiration Index (SPEI) maps have been added to the High Plains Regional Climate Center's suite of ACIS Climate Maps and are available on a daily basis on timescales ranging from 30 days to 12 months. This product was developed jointly with the National Drought Mitigation Center in cooperation with the USDA. *https://hprcc.unl.edu/ACISClimateMaps***



◄ **Figure 36: New Tools Available to Assist Tribal Nations with Drought Monitoring: As of 2021, the U.S. Drought Monitor can now be searched by tribal area, providing a more localized view of drought conditions on tribal lands. In addition to the current, weekly produced maps, data tables, and time series graphs are available. These allow for quick comparisons between current and previous conditions. *https://droughtmonitor.unl.edu/***

observations are sparse. This is especially true on tribal lands. In recent years, the U.S. Army Corps of Engineers has been working with state mesonet operators to build out a snow and soil moisture monitoring network in the upper Missouri River Basin that will be a combination of 172 retrofitted stations, along with 368 new stations. This work will increase monitoring efforts across the region substantially over the next few years. Although these efforts will ultimately help fill data gaps in the region, the immediate need to maintain and expand monitoring across the region remained largely unchanged since 2017, and therefore was a challenge to contend with during the 2020–2021 drought as well.

Composite indices, along with gridded and remotely sensed datasets, also provide beneficial information for drought monitoring. Because no single index or dataset can be used to characterize drought across the region, various combinations of metrics may be used in different geographical areas and during different times of the year. This is especially true in the more mountainous areas of the region. There continues to be a need for increased understanding of how new and existing drought metrics perform at various spatial and temporal scales, which could improve and streamline drought monitoring efforts across the region. During the drought of 2020–2021, it was also noted that deciding which metrics to use to determine drought recovery was a challenge. Therefore, there is also a need to develop best practices for the use of metrics during periods of drought recovery.

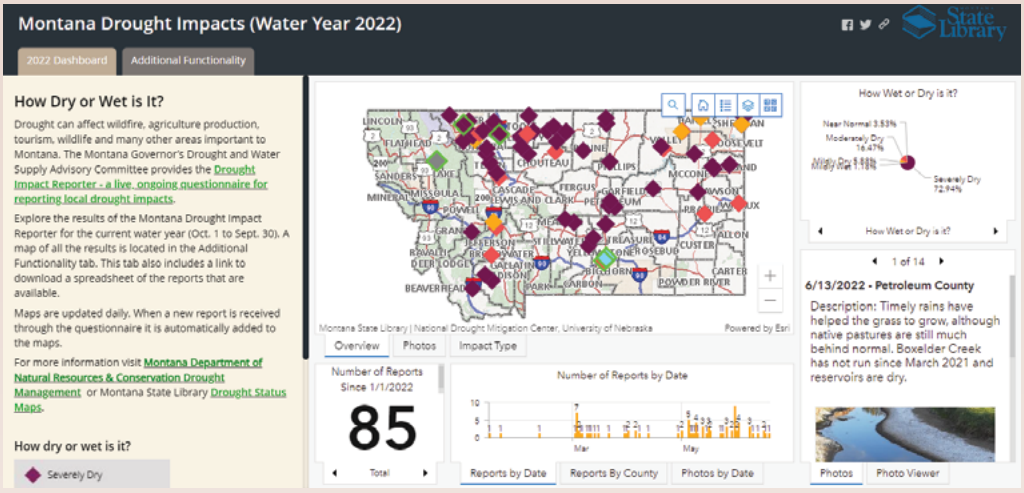
Information on drought impacts continued to be a critical part of the drought monitoring process. During the 2017 drought, localized impacts picked up on drought development prior to the more widespread data (Jencso et al. 2019). Similar observations were noted during the drought of 2020–2021, as water quality was perceived to be an early indicator of drought, particularly in South Dakota. Efforts to increase the collection and analysis of drought impact information have occurred over the

past several years. For instance, with drought a major concern going into 2021, NDSU Extension agents from each of the 53 counties in North Dakota were trained to provide condition reports during the 2021 growing season, and more than half of all the reports submitted to CMOR-Drought during 2021 came from North Dakota. These reports were used within the U.S. Drought Monitor process on a weekly basis to better assess the drought intensity across the state. Encouraging the use of tools like CMOR-Drought during non-drought periods could help to further inform state monitoring efforts by providing a baseline for comparisons.

Furthermore, in Canada, there is a need for better collaboration and communication on drought and weather impacts between various federal, provincial, private, and sector-specific groups; this includes more open sharing of data and information on a timely basis, especially between different provincial groups.

PREDICTION AND FORECASTING

Improvements in prediction and forecasting efforts have been, and will continue to be, a need for the region. There is interest from state and regional partners in convening experts from NOAA's Climate Prediction Center (CPC), who produces subseasonal to seasonal outlook products, in order to stay up-to-date on



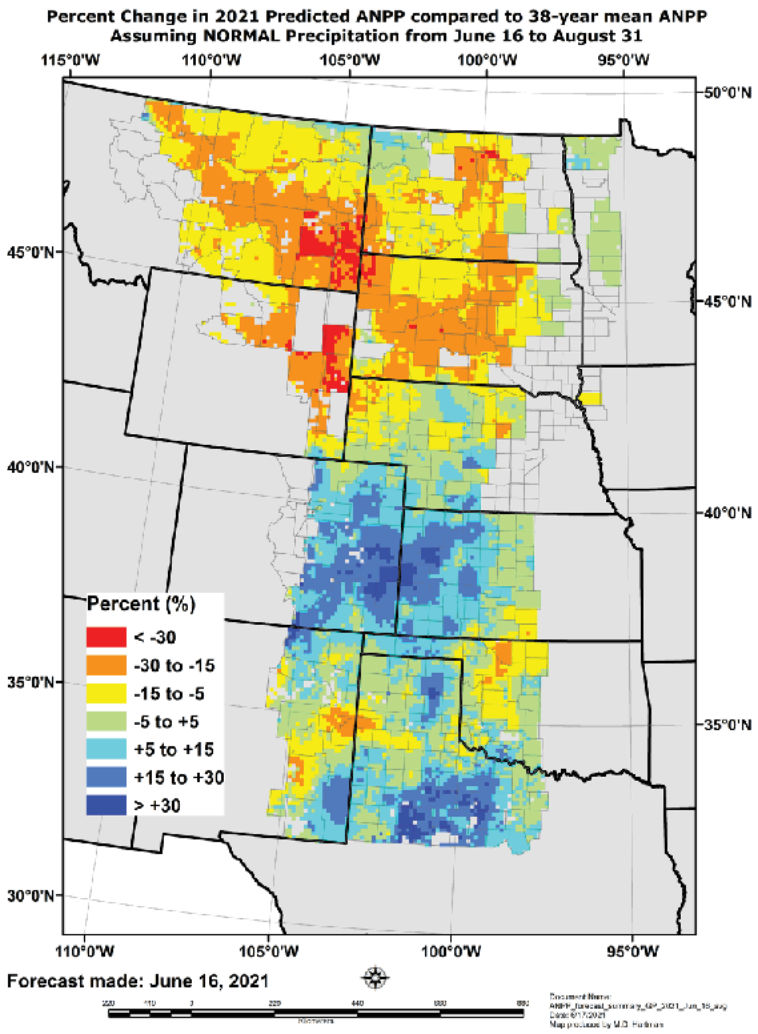
◄ Figure 37: Screenshot of the Montana Drought Impact Reporter (*nris.mt.gov/droughtimpacts*), which displays a map of reported drought impacts for the 2022 water year. Within the tool, users have various options to display reports and photos.

Montana Drought Impact Reporter—Then and Now

Montana released the Montana Drought Impact Reporter (MDIR) in July of 2017, just as the flash drought started. Public awareness and use of the tool were, predictably, sporadic at first. In the ensuing years, Montana actively promoted this tool in their drought monitoring process, and following multiple revisions to the platform, 246 responses were filed in the 2021 water year (October 2020 – September 2021). Along with the ability to provide descriptions and upload photos, data collected include an evaluation of conditions from wet to dry, crop/range conditions, planting/harvest status and date, and drought impacts for seven sectors.

In early 2021, the Montana Drought Monitoring group started hosting monthly calls with MDIR respondents and a cross section of state, federal, and tribal representatives as a strategy to collect area-specific impact data and observations of drought conditions. These calls also provided a good forum for informing stakeholders on current conditions and educating callers on the drought monitoring process in general. Many callers expressed appreciation for the opportunity to weigh in with their own observations and learn more about the process of drought classification generally.

In late 2021, the MDIR was aligned with the national CMOR-Drought tool. While Montana continues to maintain its own individual webpage, the Montana data feed directly into the national CMOR-Drought database.



▲ **Figure 38: Grass-Cast, which is an experimental grassland productivity forecast, has undergone many updates in recent years, such as increased spatial resolution and a zoomable and searchable user interface. The zoomable maps now display how much precipitation is assumed for each grid cell, which allows users to make comparisons with their own data to determine if the Grass-Cast maps are representative for their local area. Source: *https://grasscast.unl.edu***

the newest available resources. Understanding the rationale behind the outlooks would also be helpful for regional climate partners.

In 2021, NIDIS entered into a multi-year partnership with NOAA's CPC to improve the drought outlook products and services by migrating existing products to probabilistic forecasts, and incorporating new and improved dynamical and statistical forecast modeling tools. This project will also develop and improve outlook products focused on flash drought. Throughout the course of this project, CPC will identify evolving user needs and incorporate them in the product development by actively engaging with stakeholders.

PLANNING AND PREPAREDNESS

Drought planning and preparedness is an ongoing effort that occurs on all scales, from the individual rancher all the way to state, federal, and tribal governments. During the 2017 drought, it was noted that developing long-term drought plans that include both mitigation and adaptation efforts would be beneficial. Since that time, there have been a number of drought planning and preparedness projects across the region.

Each state in the region has a drought management plan, with recent updates completed in South Dakota and North Dakota. At the time of this writing, Montana was undertaking a coordinated effort to update their plan, which is slated for completion in 2023. Updates have also occurred in Canada, with the Saskatchewan Department of Agriculture revising their Drought Management Plan in 2020 to include actionable drought responses when critical thresholds were met, coordinating with the Canadian Drought Monitor classifications.

A number of Tribal Nations have developed or revised drought plans in recent years as well. For example, with funding through the BIA's Tribal Climate Resilience Program, several members of the Great Plains Tribal Water Alliance (member tribes are the Flandreau Santee Sioux Tribe, Oglala Sioux Tribe, Rosebud Sioux Tribe, Standing Rock Sioux Tribe, and Lower Brule Sioux Tribe) have conducted drought vulnerability studies and created drought adaptation plans. Currently, the Fort Peck Tribes' Water Resource Office is revising their drought plan, while also coordinating with the Water Resources/Natural Resources Department on the update to the Montana Drought Management Plan.

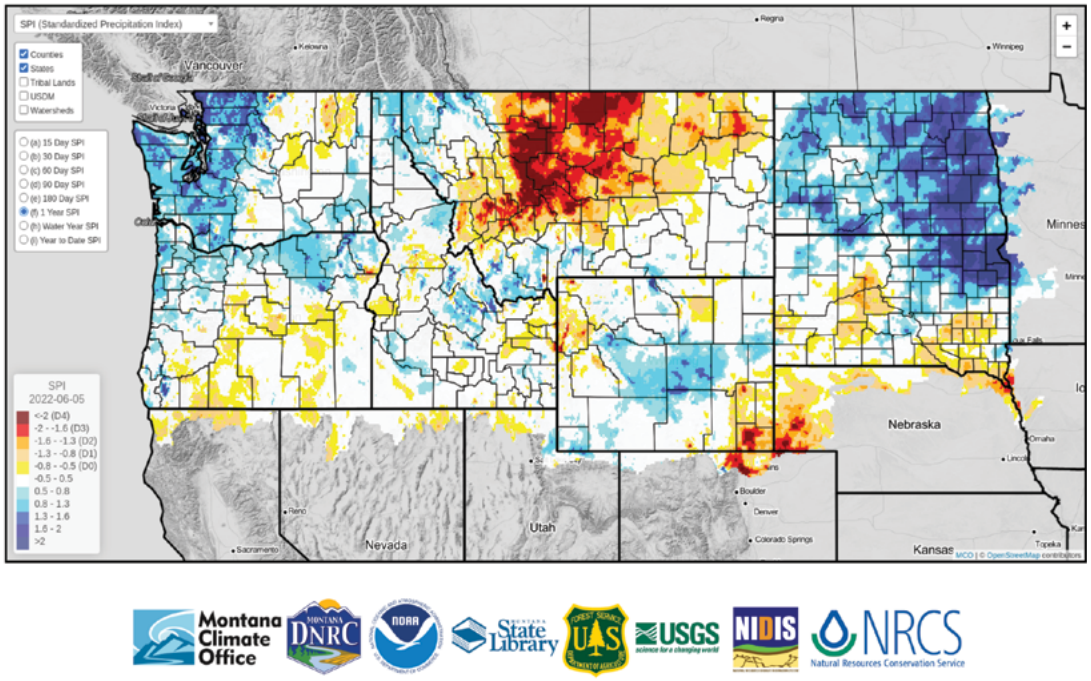
COMMUNICATION AND OUTREACH

Similar to the flash drought of 2017, drought information disseminated through social media, webinars, and briefings provided timely

TABLE 2: STATE DROUGHT PLANS IN THE U.S. NORTHERN PLAINS

State	Plan Type*	Year
Montana	Mitigation	1995 (update underway)
North Dakota	Mitigation	2018
South Dakota	Mitigation	2015
Wyoming	Response	2003

◄ **Table 2: State drought plans in the U.S. Northern Plains. *Plans that include both response and mitigation are labeled as mitigation. More information may be found here: *https://drought.unl.edu/Planning/Drought-Plans.aspx*.**



Montana Climate Office · DNRC · NOAA · State Library · USFS · USGS science for a changing world · NIDIS · NRCS Natural Resources Conservation Service

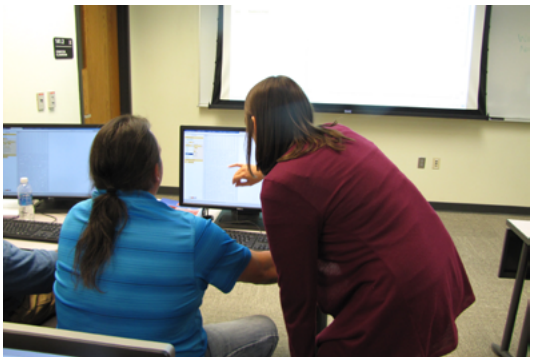
▲ **Figure 39: The Upper Missouri River Basin (UMRB) Drought Indicators Dashboard is an open-source, interactive tool which computes and displays a multitude of common drought indices and indicators on a daily basis and at various timescales that are indicative of transitions from meteorological, agricultural, terrestrial, and hydrological drought onset (*https://drought.climate.umt.edu/*). This dashboard was co-produced and developed iteratively through meetings and critique by the MT Drought Water Supply Advisory Committee (DWSAC) monitoring sub-committee, as well as inter-state and federal partners.**

information for partners, stakeholders, and the public throughout the drought. Webinars were especially popular, with several series covering topics on drought early warning, impacts, outlooks, preparedness and response, and available resources. Through feedback obtained from webinar participants, it was found that some webinars focusing on response helped support on-the-ground management decisions. Other feedback indicated that additional information sessions on available drought relief and/or management programs were needed. Follow-ups with more webinar participants could help determine if and how other information was used during the 2020–2021 drought, which could inform future webinar series.

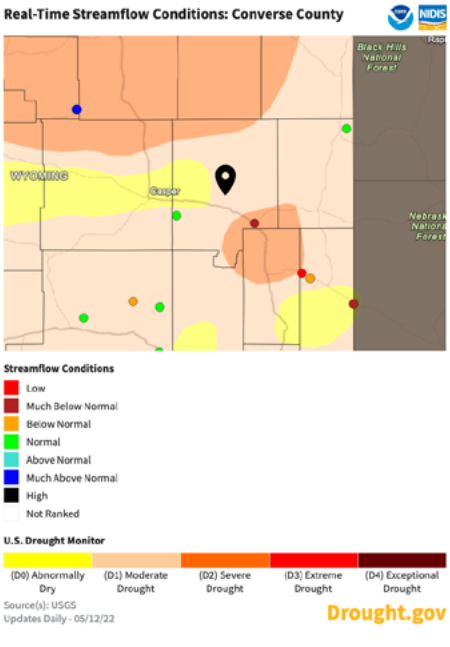
Drought generally evolved much more slowly during 2020–2021 compared to 2017, expanding and contracting, intensifying and improving as conditions changed. Because drought

was an issue for a much longer period of time, this presented challenges for communication and outreach efforts. The development of best practices for communication during longer-term droughts could help improve outreach to partners and the public. For instance, what are the most effective ways to communicate about drought as it continues over months, seasons, and years? How should short-term improvements in conditions be communicated in the context of longer-term drought? Can discussions of drought conditions and impacts be expanded to include more concrete responses and actions, particularly by sector? The development of tangible actions by sector would also be beneficial for state, provincial, and federal agencies to use.

During the flash drought of 2017, a need was identified for specialized communication, such as training sessions on drought-related resources and tools, as well as drought mitigation and adaptation strategies. Since that time, in partnership with Tribal Nations, Tribal Colleges and Universities, other universities, and federal agencies, several hands-on training sessions for tribal resource managers have taken place throughout the region. These sessions provided opportunities for a more in-depth look at various drought-related topics, while also having a chance to interact with drought-related tools in hands-on settings. Several of these sessions were funded through the BIA's Tribal Climate Resilience Program. The need for training sessions for regional climate partners and practitioners remains, especially as new resources and tools are released through time.



▲ **Figure 40: Hands-on instruction on available climate and drought tools often occurred in computer labs where tribal resource managers could delve into localized data and ask detailed questions of the instructors. Credit: Crystal Stiles, NIDIS**



▶ **Figure 41: This screenshot from drought.gov shows the U.S. Drought Monitor map with an overlay of USGS real-time streamflow conditions centered over Converse County, Wyoming on May 12, 2022.**

Drought.gov

To better serve stakeholders, decision makers, the media, and the public, NIDIS launched a redesigned U.S. Drought Portal, or Drought.gov, in January 2021. The new website features updated content and new interactive architecture designed to provide actionable, shareable information and easy-to-understand graphics describing current drought conditions and forecasts by city, county, state, zip code, and on watershed to global scales. The U.S. Drought Portal has four major new features, including drought conditions down to the city and county level, historical data and maps going back 125 years or paleoclimate data going back 2,000 years, sector-based drought information and impacts, and a "research and learn" section where you can learn the basics of drought and various drought initiatives.

INTERDISCIPLINARY RESEARCH AND APPLICATIONS

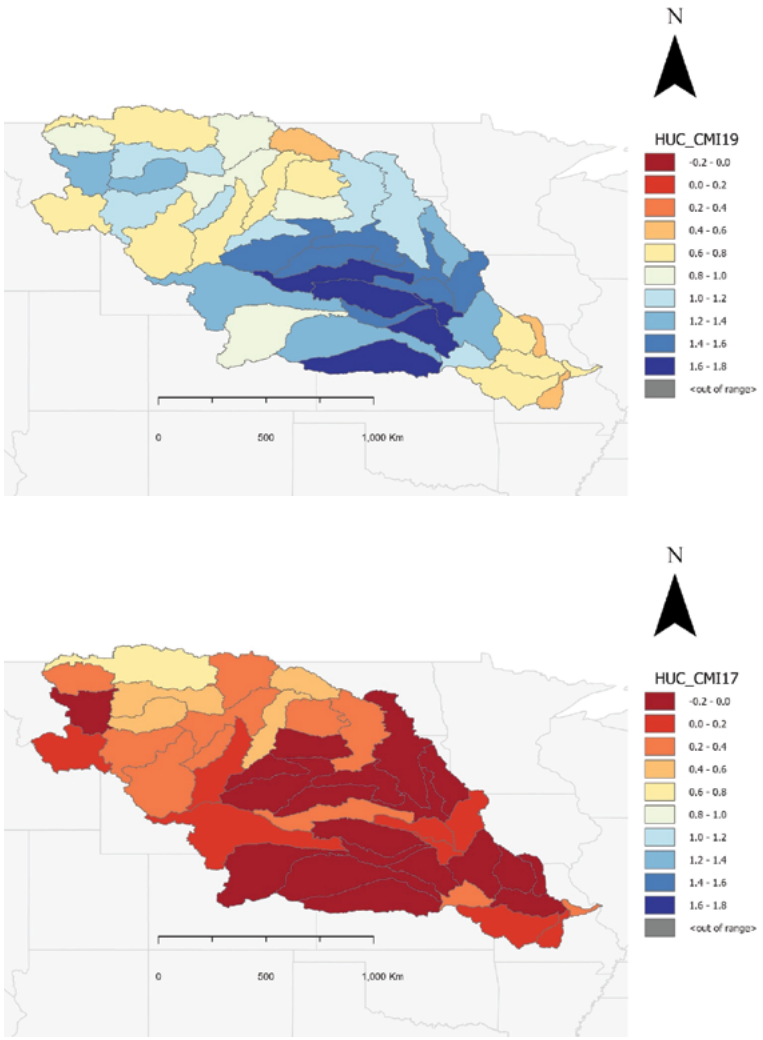
Although new research is continually advancing the region's knowledge surrounding drought issues, many questions remain. For instance, **soil moisture** continues to be an area of interest in the region. At times during the 2020–2021 drought, heavy precipitation events produced little to no runoff. This led to questions such as, what is the connection between soil moisture deficits and recharge and runoff? Can drought intensity provide insights into potential runoff, and is there a way to quantify the amount of precipitation required for recharge and runoff? Would it be possible to develop new products and tools that take into account the timing and duration of precipitation events in order to more easily provide context for these events?

Research into **drought indicators**, especially those that could be used for drought early warning, is also an ongoing need. Additionally, there is a need to understand the balance between short-term improvements in drought conditions and the longer-term drought indicators, as well as on-the-ground impacts. Identifying the most appropriate drought metrics for different areas of the region, especially as new drought indicators/indices are developed, continues to be a need.

There is interest in gaining a better understanding of the relationship between drought and **wildland fire** in the region. For instance, is there a relationship between the U.S. Drought Monitor categories and fire risk? And, how can climate data inform wildland fire-specific tools? In addition to research that is ongoing in the region, these relationships and questions are being explored more broadly though the *NIDIS Drought and Wildfire Nexus Strategy*.

There is also a need to further explore the role of **climate change** and drought in the region. For example, to what extent is climate change impacting the frequency, intensity, and/or duration of droughts in the region? Is drought the new normal? An attribution study of the 2020–2021 drought could be performed to determine the causes and predictability of the drought, what role climate change may have played, and to provide historical context for the drought.

One unique aspect of this drought was the concurrent **COVID-19 pandemic**. Research into the extent to which these two disasters impacted each other, especially in terms of preparedness and response, is needed. □



▲ **Figure 42:** ***Coming Soon:*** **A** ***Composite Moisture Index (CMI)*** **for the Missouri River Basin has been developed through the NASA DEVELOP program in partnership with the Montana Climate Office, NOAA, and the U.S. Army Corps of Engineers. This index, which can be used for drought and flood monitoring, uses various datasets to help provide a better understanding of soil moisture conditions prior to the growing season. Credit: NASA DEVELOP**

► **Figure 43:** A selection of different soil moisture sensors. Credit: Tyson Ochsner, NCSMMN

Future Opportunities in Soil Moisture Modeling

In many locations across the upper Missouri River Basin, soil moisture is a primary driver of drought impacts, especially in the context of agriculture. Despite the growing appreciation of the importance of soil moisture in drought science, accurately estimating soil moisture across scales remains a challenge. To help fill this gap, there is an opportunity to develop new soil moisture models and to more extensively integrate existing soil moisture products into drought monitoring frameworks. Traditional drought metrics can struggle to accurately describe soil water conditions, especially in topographically diverse regions such as Montana and Wyoming, in part due to the complex hydrological processes that determine soil water recharge and depletion. For example, the amount of soil moisture recharge associated with any particular precipitation event is dependent on antecedent moisture state (e.g., dry versus wet), soil texture (e.g., clay versus sand), concurrent atmospheric demand for moisture (e.g., windy, dry versus still, humid), and vegetation interactions, among other processes. Drought metrics based on historical meteorology cannot capture this level of complexity. An alternative approach is to leverage more sophisticated soil water models that better describe soil water dynamics and, importantly, account for spatial variability in soil water reservoirs (i.e., soils and topography).

A major advantage of using soil moisture models is that the complex physics that determine soil water content are explicitly modeled, providing a more objective estimation of recharge. Further, soil moisture models are flexible and can be modified to account for specific processes of interest which may vary in space and time. Given adequate periods of record, soil moisture estimates from models can be standardized using similar methods to drought metrics and provide seamless "wall-to-wall" coverage of soil moisture anomalies (or percentiles). These anomalies (or percentiles) can therefore be used directly in the national drought assessment framework following existing guidelines. Ultimately, the most appropriate soil moisture model to use will depend on location and the relative importance of physical processes.

More research is needed to assess the accuracy and uncertainty of soil moisture models for use in drought monitoring across the diverse bioclimatic and physiographic regions of the United States. This future research will help identify the critical physical processes that drive soil moisture dynamics and help to focus development of new soil moisture models. Better representation of physics becomes especially important under the context of climate change as the meteorological forcings of drought become more variable, extreme, and unpredictable. Finally, new approaches in machine learning represent a promising contemporary method to efficiently predict soil moisture conditions, especially at fine spatial resolutions. While soil moisture models are currently used in national drought assessments, their relative weight in decision-making is often limited. Future research will enhance confidence in their utility and offer an exciting means for more accurate, timely, and objective drought monitoring in an era of rapid change.

CONCLUDING REMARKS

CONTINUING THE CONVERSATION

This report provides an initial assessment of impacts and response during the 2020–2021 drought in the U.S. Northern Plains and Canadian Prairies. Some information may still be preliminary, as known impacts continue to be quantified and long-term impacts continue to be realized. As drought persists across much of the region in 2022, impacts and response activities will continue to be documented by NIDIS and partners in order to inform future efforts. Please direct any questions or comments about this report to Molly Woloszyn, Regional Drought Information Coordinator (*molly.woloszyn@noaa.gov*).

To document your local impacts to drought, please see the ***Drought Impact Reporter*** and ***CMOR-Drought*** for the U.S., and the ***Agroclimate Impact Reporter*** for Canada.

For current information on drought conditions, please see the ***U.S. Drought Monitor*** or ***Canadian Drought Monitor***. Numerous resources are also available from the ***U.S. Drought Portal***. □

Figure 44: Bison in Custer State Park, South Dakota. Credit: Tom Reichner

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